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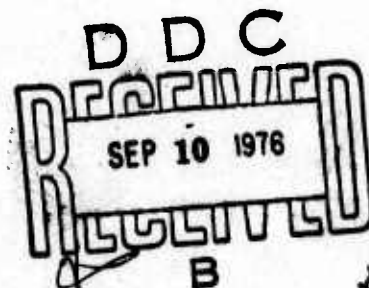DISTRIBUTION UNLIMITED.

A Methodology for Predicting Ammunition
Requirements as a Function of Force Size

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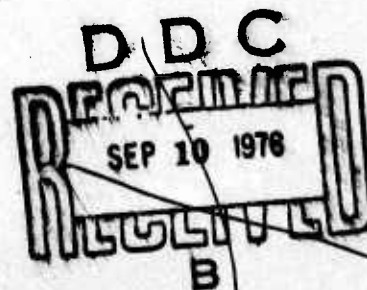
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A Master of Military Art and Science thesis presented to the faculty
of the U.S. Army Command and General Staff College, Fort Leavenworth,
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ABSTRACT

Fundamental to military planning is accurate prediction of ammunition requirements to support combat operations. Although this is a recognized fact, it is an area of planning with many uncertainties, misconceptions, and a widespread lack of understanding. In dealing with this general problem, this thesis addresses the more specific problem of the relationship of ammunition requirements as a function of the size of the force under consideration. A methodology which relates ammunition requirements to the size of the force in terms of the number of weapons of a given type in the force is proposed. A modification of the Delphi method is applied to determine the validity of the results of the application of the methodology. The research effort does not attempt to validate or refute ammunition consumption rates contained in current Department of the Army documents which contain ammunition consumption rates for planning purposes such as FM 101-10-1 and SB 38-26. The research assumes the validity of the given rates and uses these rates as the limiting values of the methodology. The author concludes that the intended purpose of the research has been accomplished and the methodology does provide useful data for predicting ammunition requirements as a function of force size.

A METHODOLOGY FOR PREDICTING AMMUNITION REQUIREMENTS

AS A FUNCTION OF FORCE SIZE

A thesis presented to the Faculty of the U.S. Army
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fulfillment of the requirements of the
degree

MASTER OF MILITARY ART AND SCIENCE

AD BELLUM PACE PARATI

Fort Leavenworth, Kansas
1976

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MASTER OF MILITARY ART AND SCIENCE

by

EDWARD M. KELLEY, MAJ, USA
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Fundamental to military planning is accurate prediction of ammunition requirements to support combat operations. Although this is a recognized fact, it is an area of planning with many uncertainties, misconceptions, and a widespread lack of understanding. In dealing with this general problem, this thesis addresses the more specific problem of the relationship of ammunition requirements as a function of the size of the force under consideration. A methodology which relates ammunition requirements to the size of the force in terms of the number of weapons of a given type in the force is proposed. A modification of the Delphi method is applied to determine the validity of the results of the application of the methodology. The research effort does not attempt to validate or refute ammunition consumption rates contained in current Department of the Army documents which contain ammunition consumption rates for planning purposes such as FM 101-10-1 and SB 38-26. The research assumes the validity of the given rates and uses these rates as the limiting values of the methodology. The author concludes that the intended purpose of the research has been accomplished and the methodology does provide useful data for predicting ammunition requirements as a function of force size.

ACKNOWLEDGEMENTS

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"It is largely a matter of determining 'how much
is enough' and 'enough for what purpose.'"

-Gen J. Lawton Collins[1]

CHAPTER 1

THE PROBLEM

INTRODUCTION

The Army is currently plagued by a lack of adequate and accurate
planning factors. This thesis is an outgrowth of efforts during the
past eighteen months to develop planning factors for inclusion in
FM 101-10-1, Staff Officers Field Manual: Organizational, Technical,
and Logistic Data, which has been under revision during that period.
The thesis addresses the more specific problem encountered in trying
to determine accurate ammunition planning factors and consumption
rates and how planning factors are effected by the level from which it
is viewed. For example, the average number of main gun tank rounds
fired per day by all the tanks in an armored division during a period of
thirty days of intense combat may be ten rounds per tank per day. This
information, although interesting may be of little use and perhaps
even an enigma to the tank battalion commander whose average number of
tank rounds fired during the same period has been three times the
division average. If the battalion's true needs are reflected by its
firing experience then for planning purposes the division experience
is useless. The use of the division average may lead the battalion to
find that it experiences a severe shortage of ammunition at a critical
time with readily recognizable unacceptable results. This example can
be applied to any weapon or organization employing weapons that consume

1

ammunition. To illustrate this point further the following example is drawn from the current documents that provide planning factors. Supply Bulletin (SB) 38-26 provides a supply rate of 5.56 rounds per weapon per day for the 105mm tank gun. This is the average rate of fire for all the M60 tanks in a force of greater than 150,000 men for a period in excess of 30 days. FM 101-10-1 shows an expenditure rate for the M60 tanks as being 20 rounds per weapon per day for a protracted period and 47 rounds per weapon per day for the succeeding days after the first day of the defense of a position. One may be led to immediately ask, "Why the big difference in these two rates and as a planner which of the rates do I use?" The question is valid and obvious but the answer to the question is not so obvious. One aspect of the situation that is unacceptable to the commander is the higher probability that some of his tanks will run out of ammunition before resupply occurs. It is the intent of this thesis to explore and explain the differences between the ammunition consumption rates contained in SB 38-26 and those contained in FM 101-10-1 and then propose a methodology which will relate the two different rates.

The design oriented method will be employed as the primary approach to this research effort. This type of study is characterized by a research design based on the results of evaluative models such as wargames or combat simulations. The method will be developed and discussed in Chapter 3. The basic approach will be to focus on the problem of accurately predicting ammunition rates under varying combat situations and as viewed by planners, staff officers, and commanders at different organizational levels within a theater of operations. There currently exist several combat simulation models and methodologies

which generate situationally dependent ammunition consumption rates.
Notable among these is the Scenario Oriented Recurring Evaluation
System (SCORES), the Division Wargame (DIVWAG) model, and the Theater
Nonnuclear Ammunition Combat Rates (THEATER AMMORATES) methodology.
There are in addition at least thirty-six other models which produce
or deal with in some manner ammunition consumption rates. The following
are among the more prominent of the models or methodologies:

(1) ASARS II   (4) PHARAC (F)

(2) CARMONETTE VI   (5) VECTOR-1

(3) DIVOPS   (6) Battalion Slice.

This research effort will draw on the results of applicable models which
will assist in solving the problem of predicting ammunition consumption
rates.

BACKGROUND

There currently exists a great deal of historical data from
actual combat experience and very detailed data from several battle
simulation models on ammunition expenditures. A problem which remains
unsolved today is how to generalize this consumption rate data into
planning factors in terms of rounds of ammunition per weapon per day,
per hour, per type battle or mission, or other unit of measure meaning-
ful to the planner. There have been a number of attempts to solve this
problem during the past sixty years with the most recent being the
Concepts Analysis Agency's Theater Nonnuclear Ammunition Combat Rates
Study (THEATER AMMORATES) for ammunition programming for the period
1978-1982 (P78-82). This study conducted annually or less frequently
as requirements dictate produces data on which the Concepts Analysis
Agency bases its recommendations to Department of the Army, Deputy

Chief of Staff for Operations (DA DCSOPS) as to what the Theater
Ammunition Rate in terms of rounds per weapon per day for the European
theater and Korea should be. DA DCSOPS provides this data to Depart-
ment of the Army Deputy Chief of Staff for Logistics (DADCSLOG) for use
in developing the rates to be published in SB 38-26 and for procurement
of ammunition. The consolidation of this data at the theater level
meets the need of the procurement and distribution planners at Depart-
ment of the Army level but does not address the planning problem of
distribution and anticipated ammunition expenditure within the theater.
Within the theater, average ammunition consumption rates vary for many
reasons, e.g., organizational positioning of the weapon such as divi-
sional and nondivisional artillery and the proximity to the battle such
as a unit in reserve versus a unit in contact with the enemy force.
Data currently provided the planners does not recognize these variations
and thus leads to confusion and misunderstanding when the data is
applied. This is a problem which continually faces planners from the
theater level to the ultimate consumer of the ammunition. This
research is intended to explain these variations thus providing a means
to eliminate the present misunderstandings.

PURPOSE

The purpose of this research is to develop a methodology which
will provide ammunition consumption rate planning factors for planners
developing estimated ammunition requirements for operations below
theater level. This purpose may be more clearly stated or understood
by saying that it is to plot the curve which represents ammunition
expenditure rates as viewed by all levels of interest from the ultimate
user to the procurement and distribution planners at Department of the

Army. Figure 1 is a curve representative of the type to be developed. Curves such as that shown in Figure 1 are proposed for, as a minimum; 105mm tank guns, 155mm howitzer field artillery guns, and TOW anti-tank weapons.
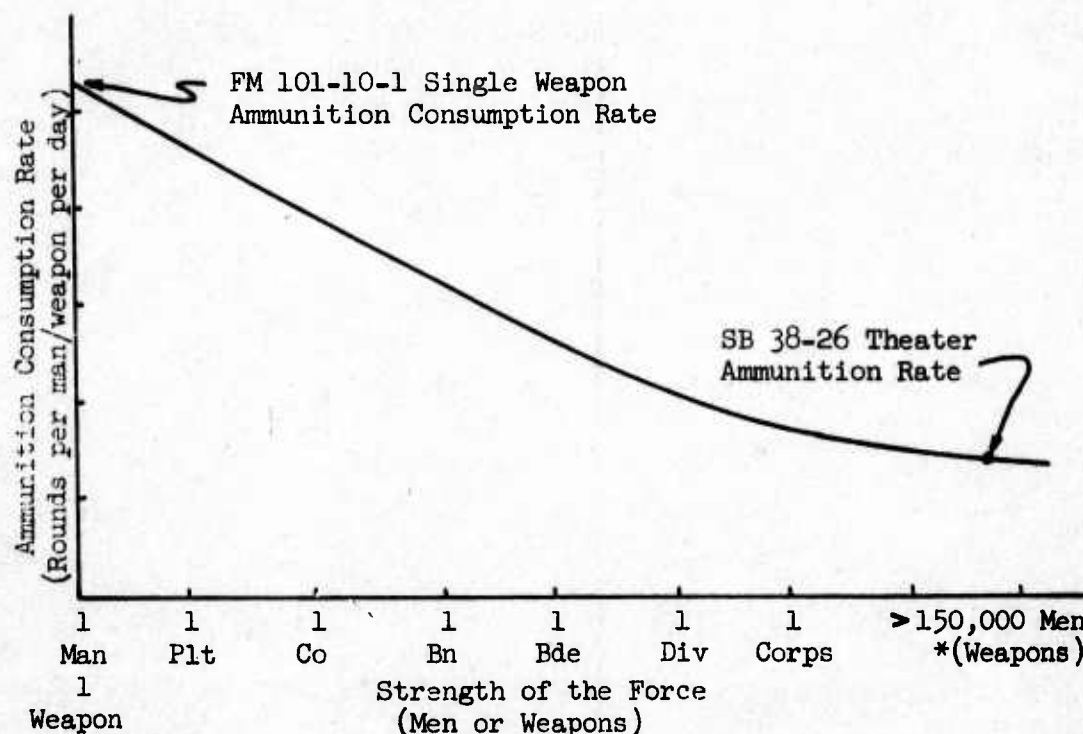
*Weapons - all weapons of a type in the force

Figure 1.

Ammunition Consumption Rate Vs Strength of the Force

PROBLEM

There are planning factors and consumption rates available today for planners and simulations and wargames such as those contained in Table 5-21 of the current edition of FM 101-10-1. The data contained in FM 101-10-1 are inadequate for several reasons, e.g., there is no differentation between divisional and nondivisional weapons ammunition expenditure rate factors; the data is purportedly based on historical data primarily WW II and the Korean War with some modification based

on studies, war gaming exercises and combat simulations; the apparent high level of aggregation and lack of indication of applicability of the factors. These inadequacies are compounded by the lack of rates for new weapons such as TOW, Dragon, and Shillelagh antitank missiles.

As a result of the extreme differences between the rates contained in SB 38-26 and those contained in FM 101-10-1 and the inadequacies of the data contained in FM 101-10-1 there are a number of misconceptions surrounding our anticipated ammunition rates in combat. Inferences drawn from the 1973 Yom Kippur War have led to misconceptions about ammunition consumption rates in combat. There was concern over the high percentage of ammunition the Israelis had fired of their prewar stocks plus supply obtained during the war. It was felt by many observers that the Israelis had to curtail firing because of ammunition shortages. One high ranking official stated[2] that ammunition consumption rates experienced by the Israelis during the Yom Kippur War were apparently higher than the ammunition consumption rates contained in FM 101-10-1. Analysis of the Israelis experience revealed that if in fact they did experience shortages it was not because their consumption rates were higher than those contained in FM 101-10-1. This example does, however, point out one of the misconceptions currently existing over the rates contained in FM 101-10-1. This is, that the ammunition consumption rates that would be experienced in a war now or in the near future would be higher than those rates contained in FM 101-10-1. This leads to the conclusion that the SB 38-26 rates which are considerably lower than the rates contained in FM 101-10-1 are invalid. Although this idea is held by some, there is no data to substantiate this conclusion. Based on considerable research into this problem this researcher

has concluded that the FM 101-10-1 rates exceed, with a reasonable degree of certainty, rates that would be experienced in combat now or in the near future. It is further understood that since the FM 101-10-1 rates are for application to a single weapon and the SB 38-26 rates are for application to all the weapons of a force greater than 150,000 men the Supply Bulletin 38-26 rates of supply will in fact support those weapons in the theater that are able to experience the rates of fire shown in FM 101-10-1. More simply stated, the SB 38-26 theater ammunition rates will supply adequate ammunition to the theater to conduct the battle and meet the needs of the combat situation consideraing all intensities of sustained combat over a considerable period of time, i.e. in excess of 90 days sustained combat.

ASSUMPTIONS

As may have been concluded by this point a basic assumption must be made concerning the ability to relate the single weapon rate of fire, the ordinate of Figure 1, to the SB 38-26 average theater rate of fire. This assmuption is that there exists a relationship between these two rates. In the following section a hypothesis is drawn based on this assumption. At this point a bit of intuitive reasoning is required to arrive at this assumption.

General W. B. Palmer has stated that there is no relationship between the theater ammunition rate or "ammunition day of supply" and the "amount of ammunition which may be fired on any one day, through any particular number of guns, in any given situation." If this statement is accepted at face value then the research need not be continued. This researcher has concluded though that: (1) General Palmer's statement is his own personal conclusion based on the facts

and assumptions he had at hand at the time he drew the conclusion and (2) the ultimate basis today for the rates contained in SB 38-26 are the individual weapon's rate of fire and therefore there must be a relationship of some kind between these two rates in order for us to arrive at the theater rate or day of supply.

This was not necessarily the case in 1953 when General Palmer made the above statement. At that time the average theater rate was determined by dividing the number of rounds consumed in the theater during a specified period by the average number of weapons in the theater during that period. Today the theater rate is determined, as is discussed in more detail in Chapter 2, by building up through the THEATER AMMORATES methodology, the casualties, both to men and equipment by the firing of ammunition in small unit engagements. The number of these engagements during the period under study is determined by the objectives of the opposing forces and their ability to carry out their objectives, i.e., the battle scenario.

The danger of making this assumption and perhaps oversimplifying a complex problem is recognized. However, if a complete analysis is made of the factors which lead from the individual weapon firing in combat to the theater average rate of fire and each of these factors is incorporated into the equation for the theater rate then the danger of oversimplification will be eliminated. It is the intent of this research to insure that each factor is adequately addressed and placed in proper perspective in the theater rate equation.

If the theater ammunition rate equation is depicted in a manner in which the individual weapon ammunition consumption rate is an element, it can be written as follows:

$$TR = f(T + NE + E + WR + C + U)$$

Where,

        TR - theater ammunition rate or day of supply

        T - effects due to the length of the period considered (time)

        NE - nature of the enemy force

        E - the effects of the environment (including terrain effects)

        WR - individual weapon ammunition consumption rate

        C - climatic effects

        U - unknown variables which the analysis leads to the conclusion that they exist but cannot be measured or do not meaurably effect the outcome of the solution.

Or in words, the theater ammunition rate is a function of the time (T) under consideration plus the effects of the environment, the individual weapon ammunition consumption rate, the effects of the climate and those unknown variables which analysis shows exist but are either immeasurable or do not significantly effect the theater rate yet are known to exist. One such item which would fall into the unknown variable category is the percentage of weapons that will be fired during an engagement. This variable must of course be considered because of the importance it plays both in terms of the outcome of the battle and the effect on the amount of ammunition that will be fired but in the final analysis after all things are considered, the value of this variable is subjectively determined and then assumed.

HYPOTHESIS

The relationship between the individual weapon consumption rate provided in FM 101-10-1 and the rate provided in SB 38-26 can be acceptably represented by assuming a linear relationship for a force of a division size or smaller and a relationship of the form:

$$y = \frac{b - a}{x^n} + a$$

for a force of division size or greater where,

> y - is the ammunition consumption rate
>
> b - division average consumption rate
>
> a - theater average consumption rate
>
> x - weapon density multiplier ($x = 1$ for the weapons in a division size force and x would equal 3 for a three division size force where the three divisions are of the same type and have the same number of weapons of the type under consideration)
>
> n - the power of x which forces the relationship over the range of x greater than 1 and x less than or equal to the value of x associated with the SB 38-26 force used to determine the theater ammuntion rate for the weapon under consideration. An additional characteristic of n is that it forces the curve depicting the ammunition consumption rate to be tangential to the linear relationship for the force of less than a division size at the division point on the graph and tangential to a horizontal line passing through the theater ammuntion rate at the point that rate is determined.

The curves which result from the application of this hypothesis appear as shown in Figure 1, page 5.

IMPORTANCE

The importance of being able to accurately determine the amount of ammunition required cannot be overemphasized. The casual observer may say that is a rather obvious conclusion, however, in practice the importance of the obvious has been neglected. It appears to have been quite the norm for the commander or his operations officer to turn to the logistician and ask how much ammuntion was needed for an operation rather than trying to solve the problem in the realm of the operational problem whence it came and is a part. If the logistician responded that

he had no idea what the need was then the next question to him was,

"Okay then, how much is available?" It is a difficult problem though

and without sufficient experience to draw from it is easier to make a

guess as to whether the ammunition available will be enough and thus

the logistician becomes very involved in the operational aspects of

the planning and execution, first to insure that the best guess is

made and then to insure that sufficient ammunition is made available

when needed. Nowhere in this process did anyone wrestle with the

difficult problem of "how much does it take to do various different

jobs under various different curcumstances?" Or, "how much of a job

can we do with what we've got?"

CHAPTER 1

FOOTNOTES

[1]Dorothy K. Clark, <u>Ammunition Day of Supply, WW I to 1960</u>, Technical Paper ORO-TP-18, December 1960, p. 7.

[2]U. S. Army Forces Command, letter dated 7 December 1974, subject: "Ammunition Basic Loads."

"General Maxwell D. Taylor, Commanding General of the US Eighth Army in Korea, said at the close of the war that he could not judge whether 1/10 or 10 times as much ammunition should have been expended in Korea."[1]

CHAPTER 2

REVIEW OF RELATED LITERATURE

OVERVIEW

This review of literature related to ammunition expenditure will touch on the following:

1. A historical perspective of ammunition consumption rates and procedures for determining ammunition requirements.

2. The ammunition day of fire. This is a term descriptive of the approach to ammunition during WW I.

3. The ammunition unit of fire. The ammunition unit of fire was used for ammunition planning during WW II.

4. The ammunition day of supply. This is a term descriptive of the current approach to ammunition planning.

5. The use and potential use of wargames and simulations to assist in determining ammunition requirements.

6. An overview of representative studies concerned with ammunition consumption and resupply.

HISTORICAL BACKGROUND

During the past sixty years the approach to determining how much ammunition would be made available to combat operations has varied between emphasis on the weapon capability to fire and the capability to produce ammunition, i.e., competition for resources.[2]

Ammunition Day of Fire

The 1918 Handbook of Ordnance Data stated that "the initial allowance of ammunition for the Army in active operations is, for field and heavy artillery, a number of days of fire."[3] The day of fire was a theoretical quantity of ammunition, normally expressed in rounds, expected to be consumed during a day of combat operations. Its primary purpose was to aid in determining supply requirements both from the standpoint of the supplier and the user. To determine how much ammunition would be on hand in combat units, the units were allocated a number of days of fire, e.g., units in contact with the enemy were allocated three days of fire at the unit, and four days of fire in supporting depots.[4] The 1918 Ordnance handbook gave some indication that although the day of fire was the accepted method for alloting ammunition there was some doubt as to the adequacy of the approach.[5] This doubt was nurtured by the French experience which gave much lower expenditures than the U. S. expected expenditures. This can be seen by the U. S. allocation of 300 rounds per 75mm artillery tube per day and 100 rounds of 155mm per tube per day versus the French firing experience for five months during April through September 1917 of 40 rounds per 75mm tube and 20 rounds per 155mm tube.[6]

One impression that strikes this author is that regardless of the amount of ammunition provided, in general, conditions permitting, it was always fired up. This thought is supported by that of General Taylor[7] and the WW I experience. Artillery ammunition expenditures increased excessively during WW I over the experience of previous wars. For example, during the Civil War, Union forces fired 1,950,000 rounds of artillery ammunition during the year ending 30 June 1864, while

American Forces fired 8,100,000 rounds of artillery ammunition during the year ending 10 November 1918. This of course can be attributed to many factors but certainly among these two key factors are the greater capability of artillery pieces and greater production and supply capabilities.[8]

Ammunition Day of Supply

The end of WW I came at a time when the American military industrial machine was just beginning to produce the great quantities of supplies, weapons and general equipment being demanded to support the war effort.[9] This situation left the U. S. Army with a great stockpile of deteriorating weapons and ammunition that were soon to become obsolete.[10] It is apparent that this situation and the WW I ammunition consumption experience led to some analysis which resulted in the War Department publishing, in 1921, a list of "Allowances in rounds per weapon per day and percentages of types" and in 1929, "Rates of Fire and Percentages of Type of Ammunition To Be Used in Connection with the Computation of War Requirements and Obtaining of Production Data."[11] Although this research has not determined the specific date, it is obvious from the rates published in 1935 that the decision had been made to use significantly lower rates termed, "day of supply" for production instead of the day of fire rate used in WW I. A table published 1 July 1935, entitled, "Day of Supply of Ammunition for the Zone of the Interior and for Theaters of Operation," provided 75mm howitzer rates as 40 rounds per weapon per day and 155mm rates as 20 rounds per weapon per day. The 155mm rates dropped to 15 rounds per weapon per day in 1938 where they remained until December 1944 when the rate was increased to 20 rounds per weapon per day.[12]

Ammunition Unit of Fire

The ammunition day of supply provided the basis for ammunition supply planning and procurement during WW II.[13,14] This approach essentially remains the accepted method for determining ammunition stockage levels today. SB 38-26 provides the theater commander an authorized number of rounds per weapon per day and Department of the Army provides him an authorized number of days of supply. The multiplication of the number of rounds per weapon per day, the number of days of supply authorized, and the number of weapons of a particular type provide the theater authorized stockage lever of ammunition.[15] Today the ammunition day of supply is used for supply planning, procurement, and ammunition supply to overseas theaters. This was not the case during WW II. At times during WW II the ammunition day of supply was referred to as the ammunition that should come from the factories each day.[16] Determining ammunition requirements for a specific combat operation was apparently considered to be a different problem. Ammunition requirements for the North African campaign were based on the ammunition "unit of fire." The unit of fire was in essence the old WW I day of fire renamed.[17] The unit of fire was defined in the October 1943, edition of FM 101-10, as "a tactical unit of measure" and "based upon experience in the theater." The same wide variance existed between the unit of fire and the day of supply that now exists between the theater ammunition rates of today and the ammunition rounds per weapon per day rates contained in FM 101-10-1. This author has not been able to find any recorded attempt to explain the wide variance between these two rates. As a result of this research, to date, this author has been drawn to conclude that

although the day of supply provided enough ammunition over the long haul, tactical commanders have been reluctant to accept the lower rates it offers. This reluctance led to the unit of fire in WW II and the current FM 101-10-1 ammunition consumption rates. Both the unit of fire and the FM 101-10-1 rates appear high when considering average consumption rates actually experienced. However, there have been enough occasions in combat to convince commanders that the higher rates such as the unit of fire are justified when planning for and supplying combat operations. Additionally the higher rates provide an additional margin of assurity that they will not run short of ammunition at some critical point in the battle. When this approach is taken to ammunition supply, surpluses of ammunition and a higher rate of deterioration must be anticipated. Such was the case in the history of units employed during the advance on Rome in 1944. The ammunition unit of fire was used to determine supply requirements. After allied forces passed Rome, the Peninsular Base Section ammunition company found approximately 10,000 tons of abandoned ammunition.[18] This constituted approximately 5 percent of the 175,000 tons of ammunition expended during the three months campaign.[19]

WW II experience with the day of supply and the unit of fire resulted in the following definition of the day of supply in the August 1949 edition of FM 101-10:[20]

> "The day of supply is frequently multiplied and used to express the estimated ammunition requirement by theater, by base, or by tactical unit (army group, army, or similar unit). Quantities so delivered will sustain a balanced force of not less than 150,000, but will require agumentation if applied to a smaller force. Except as a basis of estimating ammunition requirements for such units, the term 'day of supply' has no application to tactical units in the combat zone (as division, corps, etc.)."[21]

Change 1 to the 1949 edition of FM 101-10 omitted the above definition
of the day of supply and provided the statement:

> "It (the day of supply listed in SB 38-26) is applicable
> to a balanced theather army command, of not less than
> 150,000 men and will require evaluation and may require
> adjustment should the army command be unbalanced or
> consist of a lesser number."[22]

The published rates of the day of supply following WW II and
based on WW II experience first appeared in Supply Bulletin 38-4-WD,
29 May 1947.[23]

It has been stated[24] that from the standpoint of ammunition
requirements and supply the Korean War was to a degree WW II all over
again on a much smaller scale. Afterwards as well as during the war
the arguments were over the sufficiency of certain types of ammunition
and as to be expected, 'how much is enough.' Speaking before a Senate
Subcommittee of the Committee on Armed Services, General W. B. Palmer,
Assistant Chief of Staff G4 had this to say about the ammunition day
of supply and the authorized stockage level of ammunition:

> "No...allocation system..., governing the flow of heavy
> tonnages of ammunition on a world wide basis, could
> operate without fundamental statistical controls. These
> controls, essentially simple in character, come down to
> two professional terms...(a) the ammunition day of supply,
> (b) the authorized stock level. The ammunition day of
> supply for a particular weapon is the average quantity,
> in rounds, which experience dictates can be expected to
> be fired by each of these weapons in the hands of a
> large body of troops over an extended period of time.
> In effect, this is a unit of measure. It is the basic
> measure used for planning, procurement, and supply
> purposes. It has absolutely nothing to do with the
> amount of ammunition which will be fired on any one day,
> through any particular number of guns, in any given
> situation. This I consider a vital distinction, and one
> which neglected, has been responsible for much confusion
> in terms...
>
> "Authorized stock level is...the product of the average
> day's supply for a particular weapon, multiplied by the
> number of weapons in the theater, multiplied by the

number of days' supply deemed essential to have on hand.

"Many elements come together in determining the authorized stock level by the method described. A balance must be maintained among reserve levels at home, the time for resupply, and a minimum safety level in the theater, as well as an operating stock of ammunition above the safety level, which is necessary to provide flexibility and efficiency in handling. These factors are tied together in setting for an overseas theater the number of days in its authorized stock level.

"A prudent commander thus operates his authorized stock level as does a prudent householder his bank account. With a minimum balance below which he will not normally draw so as to provide insurance for a rainy day, he operates with the balance, and after every heavy drain, prudently builds anew his reserve...Circumstances may dictate a change in any one of the three variables entering into the equation. A change in any one or in two can produce most marked changes in the total number of rounds involved..

In September 1951 there were on hand in the Far East 175 days of supply of the 105H ammunition. A month later, in October, the level had dropped to 85 days of supply. Yet the actual number of physical rounds had dropped only 8%, while the number of days of supply was cut in half. The reason for this paradox was that the number of guns had been increased from 678 to 698, and the authorized rate per gun had been increased from 30 rounds to 55 rounds..."[25]

Although General Palmer understood and had the problem well in hand, the argument did not end there. Paradoxically, perhaps it never will as long as the range of solutions is so broad and the final decision rests with a single responsible individual.

The unit of fire does not appear in U.S. ammunition planning literature after WW II. The reason for this is not clear as the concept still appears to have utility. One outgrowth of the unit of fire is the table of single weapon ammunition consumption rates contained in the current edition of FM 101-10-1.

The day of supply provided the basis for ammunition management during the Vietnam War. With the rapid buildup of U.S. forces in

Vietnam during 1965 and 1966 and little experience of the type to be gained, the ammunition day of supply was at first based on the WW II and Korean War experience.[26] "Push packages" based on a number of days of supply were shipped or flown to Vietnam as necessity dictated in order to meet combat unit deployment schedules. The major issue during early 1966 was the problem of determining accurate supply rates.[27] Through intensive management, beginning at the highest levels of the Department of Defense and the Department of the Army, by the informally established Office of Special Assistant for Munitions, headed up by Brigadier General Henry A. Rasmussen critical ammunition shortages were eased. Out of this ammunition management program resulted new supply rates deemed necessary to support combat operations in Vietnam. These new rates were higher than previously published day of supply rates. There were two rates published; one for an "Intense Combat Rate" and the second for the "Theater Sustaining Rate." Although these rates were primarily based on experience gained during the 1968 Tet offensive[28] the 155mm howitzer intense rate of 150 rounds per weapon calls to mind the day of fire and unit of fire rates.

WARGAMES AND SIMULATIONS

With the emergence of the techniques of Operations Research and Systems Analysis during the late 1950's and early 1960's as tools to assist in decision making considerable effort was spent applying these techniques to the problem of estimating ammunition requirements. During 1960 the Operations Research Office of the Johns Hopkins University, later to become the Research Analysis Corporation, began a study to provide "an estimate of the Army's daily ammunition needs."[29] This effort subsequently evolved into what is now known as a

the Nonnuclear Ammunition Combat Rates Methodology (THEATER AMMORATES) which has been discussed in Chapter 1. The THEATER AMMORATES methodology is made up of ten models which simulate an aspect of combat. These models are:[30]

1. Artillery Casualty Assessment Model.

2. Red Artillery Model.

3. Blue Artillery Model.

4. Target Acquisition Model.

5. Theater Rates Model.

6. Infantry Combat Model.

7. Tank/Antitank Simulation.

8. Helicopter Antipersonnel Model.

9. Helicopter Antiarmor Model.

10. Air Defense Model.

The ammunition rates resulting from the processing of this methodology by the Concepts Analysis Agency, after staffing and approval are published in SB 38-26 for use by theater commanders in developing their war reserves of ammunition.

There are many additional models and simulations which produce consumption rates of war materiel. Several of these are mentioned in Chapter 1 and available data drawn from some of the simulations is provided in Appendix B. Although the predominance of systems analyst who the author has interviewed who work with these simulations have indicated their feelings that the simulations represent intense combat, their feelings were that the ammunition consumption rates from the simulations must be used with care as they may be extremely high. This may be the case, however, the rates resulting from the THEATER

AMMORATES methodology are in general among or comparable to the lowest
rates from all sources this author has found. This situation brings
up an apparent inconsistency which it is intended that this research
will eliminate or at least relieve.

REPRESENTATIVE STUDIES

In addition to THEATER AMMORATES several ammunition rate
related studies have been conducted during the past three years. The
U.S. Army Logistics Center has conducted two studies on ammunition con-
sumption rates. The first, conducted in 1973 in coordination with
18th Airborne Corps, was to determine ammunition requirements for the
Airborne "D" Package. Ammunition consumption was not the only problem
addressed by the study as the study addressed all types of logistics
support the force would require. This study concentrated on an
airborne division in combat in a Mideast scenario. Subsequent to
this study and drawing on experience gained in conducting the Airborne
"D" study the Logistics Center developed a methodology to determine
ammunition requirements in support of the SCORES (Scenario Oriented
Recurring Evaluation System) process. This procedure, named by the
Logistics Center, A Methodology for Computing Ammunition Resupply
Requirements for Support of Deployed Forces (3D Package) provides an
estimation of ammunition expenditures for a SCORES scenario. The
procedure does not develop consumption rates. The procedure uses
consumption rates from both SB 38-26 which are contained in the
Logistic Center's LOG DATA BASE (an automated system previously
named REREQ (Resupply Requirements Generator)) and FM 101-10-1 and
provides the total rounds and tons of ammunition consumed. Thus the

accuracy of the approach is dependent on the accuracy of the source rates.

The most recent work done to predict ammunition expenditures, other than THEATER AMMORATES, was a study by the Combined Arms Combat Developments Activity, Combat Operations Analysis Directorate. This study, titled, SCORES Ammunition Expenditure Analysis[31] drew on the LEGAL MIX IV model to determine how much ammunition was fired and the STARMAN C target acquisition model to determine which targets should be fired upon and in what priority. The purpose of this study was:

1. To develop the capability at CACDA to accurately predict artillery and mortar ammunition expenditures.

2. To acess the levels of effectiveness for the ammunition expenditures rates.

3. To make an assessment of two SCORES scenarios ammunition requirements.

4. To compare the results of the above assessment with other procedures that either had been or could be used to estimate the ammunition requirements of a specific SCORES scenario.

The conclusions of the study were:

"that the LOG Center's Methodology and FM 101-10-1 give accurate estimates of artillery and mortar ammunition requirements in a much faster manner than the detailed methodology used in this (study)."[32]

SUMMARY

A conclusion that one cannot help but draw from the related literature is that planning for ammunition requirements for a force is an area of extreme uncertainty. This uncertainty leads to a better understanding as to why there has been so much difference in opinion

over these past sixty years as to which rates should be used for

what purpose. Perhaps these same problems go far beyond the sixty

years considered by this **literature** review. This is without doubt an

area for potentially fruitful study and one in which the potential

returns are high. The casual observer may think this is not really

such a big thing but recall the 10,000 tons of ammunition left at fir-

ing positions on the way to Rome. Two thoughts come to mind in

connection with this occurance: First, this 10,000 tons of ammunition

could easily represent 10-20 millions of dollars and second, as a

result of the excess at the firing positions how much ammunition was

fired just because it was available? Certainly no one would inten-

tionally deprive the infantryman or the artilleryman of the ammunition

he needs to conduct the battle. However, there are occasions when he

has no concept of what his real needs are. The planner enters in at

this point and must provide the necessary insight to develop the best

estimate of the real requirements, the true needs. The planner must

also be prepared to show why his predictions represent the real needs.

Other than the THEATER AMMORATES work, our efforts don't appear to

have been very seriously focused on predicting what the true ammunition

needs are and to determine what an appropriate rate of fire is.

Perhaps this is an impossibility but it seems to this observer that a

great deal can be done to at least provide a better understanding of

the problem. The better understanding would then lead to better

estimates of requirements. Without this understanding the wrong

conclusions can be drawn from situations such as the 1973 Middle

East War. This is not to say that any particular conclusion drawn

was wrong; however, when two completely opposite conclusions are drawn

from the same action one cannot help but ask why.

This brief look into the literature related to the subject of ammunition consumption rates has further shown this author the urgent need to study this subject in as great detail as time permits. Also there is a definite need for a better understanding of the factors that go to make up the required ammunition consumption rate.

CHAPTER 2

FOOTNOTES

[1]Dorothy K. Clark, Ammunition Day of Supply, WW I to 1960, Technical Paper ORO-TO-18, December 1960, p. 40. Note: Dr. George Rice of Texas A&M University has suggested a paraphrase to Gen. Taylor's remarks in the following questions. "Or, did we spend more because we had more? Could we have done the job with less? How much is the minimum? Comfortable? Luxurious? Excessive?"

[2]Clark, p. 2.

[3]Clark, p. 9.

[4]Clark, p. 9

[5]Clark, p. 9.

[6]Clark, p. 9.

[7]Clark, p. 40.

[8]James A. Huston, The Sinews of War: Army Logistics 1775-1953, (Washington: U.S. Government Printing Office, 1966), p. 398.

[9]Huston, p. 388

[10]Clark, p. 10.

[11]Clark, p. 12

[12]Clark, pp. 11 & 12.

[13]Huston, p. 462.

[14]Clark, p. 14.

[15]U.S. Department of the Army, HQ, Department of the Army, Supply Bulletin, SB 38-26.

[16]Clark, p. 14.

[17]Clark, p. 14.

[18]U.S. Army Headquarters, Mediterranean Theater of Operations, 1st Indorsement dated 29 November 1944 to letter, Army Ground Force Board, dated 2 November 1944, subject: "Ammo Joe's Advance on Rome."

[19]Army Ground Forces Board, letter dated 2 November 1944, subject: "Ammo Joe's Advance on Rome," p. 3 of report.

[20]Clark, p. 20.

[21]U.S. Department of the Army, HQ Department of the Army, Field Manual, FM 101-10, with Change 1, Staff Officers Field Manual, Organizational, Technical, and Logistical Data, August 1949.

[22]_____, _____, FM 101-10, August 1949.

[23]Clark, p. 32.

[24]Clark, p. 33.

[25]Clark, pp. 33 & 34.

[26]Joseph M. Heiser, Logistics Support: Vietnam Studies, Washington: Department of the Army, 1974, p. 110.

[27]Heiser, p. 107.

[28]Heiser, p. 111.

[29]Clark, p. 1.

[30]Charles E. Van Albert, Nonnuclear Ammunition Combat Rates Methodology Improvement, Part II, (AMMIP-II), Final Report, Bethesda, Md.: U.S. Army Concepts Analysis Agency, December 1974, p. 1.

[31]Frederick F. McClintic and Timothy J. Bailey, SCORES Ammunition Expenditure Analysis, ACN 21698, Fort Leavenworth, Ks.: Directorate of Combat Operations Analysis, U.S. Army Combined Arms Combat Developments Activity, June 1975, p. 1.

[32]McClintic, p. v.

There is nothing more difficult to take in hand, more
perilous to conduct, or more uncertain in its success,
than to take the lead in the introduction of a new order
of things.

                                        Machiavelli
                                        The Prince

CHAPTER 3

METHODOLOGY

OVERVIEW

Ideally the approach to solving the problem at hand would appear
to be analytical, straight forward, with a minimum of nuances, and
statistically supportable. Such is the approach taken by the Concepts
Analysis Agency in their Theater Ammunition Rates Study without a
statistical analysis and without covering all the organizational levels
considered in this thesis, i.e., the Theater Ammorates Study results
address only the theater level aggregated rates.

As ideal as this approach might appear to be it has not met
with a great deal of acceptance. The approach seems to many to
provide rates which are much lower than they had envisioned through
their preconceived notions or experience. An example of this assertion
is the 105mm gun on the M60A1 Tank which has a theater rate (SB 38-26)
of 5.6 rounds[1] per weapon per day and FM 101-10-1 which has a pro-
tracted rate for the same weapon of 20 rounds[2] per weapon per day.
This situation is made more complex and perhaps confusing to the
observer when he looks at the 105mm tank gun rate of 47 rounds[3] per
weapon per day for the succeeding days after the first day in the
defense of a position. Thus his tendency is to reject the results of

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the purely analytical approach as providing him rates which are too low and will not support his ammunition needs. Many reasons can be cited as to why the rejection of the lower rate may be premature but seldom are these reasons requested and even less often is someone knowledgeable enough available to offer an explanation. Thus we reach an impasse which tells us that the purely analytical approach, unless frequently and adequately explained provides unacceptable results.

From this impasse we look to a methodology based on collective military judgement. There are some pitfalls to this approach, some of which are: a tendency to exaggerate the experience, limited experience, suboptimization, a tendency to relate needs with capability to consume. There is also the problem of new weapons systems such as TOW and Dragon for which there is limited or no experience. Another problem which is endemic in our society is that needs are quite often confused with and equated to what is available. This problem was highlighted in a recent conversation between the author and a U.S. Army colonel[4], who is in a position to influence the planning process, when he asked if we were anywhere near getting away from the terms required supply rate (RSR) and available supply rate[5] (ASR) currently used in ammunition planning. He went on to explain that he felt the current approach where the RSR was determined by operations planners and provided to logistics planners who in turn provided the ASR was a backwards approach. He further stated that the logistician should provide the operations planner with the ASR and let the operations planner start from there. His contention here was that this would stop the operations planners from placing unrealistic requirements on the supply system. There is definitely logic in this

contention, however the logic is based on the premise that the RSR will always exceed the ASR. Perhaps this is indicative of the widespread lack of knowledge that except for very limited and highly specialized cases, ASR's were not imposed in Vietnam. The evidence from the Vietnam experience indicates that as a result there was considerable ammunition fired for which no need existed.

In this realm intuitive reasoning leads us to the conclusion that if a solution is obtainable to the problem it must lie somewhere between the purely analytical and the purely subjective. What such a methodology would attempt to do is capitalize on the best qualities of each approach. At every step provide explanation to the user as the logic behind each step of the methodology. The methodology will extend beyond the thesis into the routine planning process.

The basic analytical elements of the methodology involve the Theater Ammunition Rates methodology, primarily in terms of rates published in SB 38-26 and the hypothesis stated in Chapter 1. The hypothesis stated in Chapter 1 is of course a purely analytical rendering of the data currently contained in FM 101-10-1, and SB 38-26 and an assumed or analytically or statistically determined rate of fire for a division.

RESEARCH METHODOLOGY

The research methodology as depicted in Figure 2, first begins with the development of the analytical aspects of the hypothesis. From this point we are able to determine those data elements that must be determined to prove or disprove the hypothesis. A statistical analysis of the data elements would be included if enough data elements were available to support such an analysis. The data collection

effort has been in part supported by a special study project being conducted by five CGSC students developing ammunition consumption rate data for FM 101-10-1. Each element of the methodology is discussed below.

```
┌──────────────┐                    ┌──────────────────┐
│ Analytical   │                    │ Research to Develop │
│ Development  │                    │ Emperical Data   │
└──────┬───────┘                    └────────┬─────────┘
       │                                     │
       │                            ┌────────▼─────────┐
       │                            │ Emperical Data   │
       │                            │ From Research    │
       │                            └────────┬─────────┘
       │                                     │
       │                            ┌────────▼─────────┐
       │                            │ Analysis of      │
       │                            │ Emperical Data   │
       │                            └────────┬─────────┘
       │        Essential Data               │
       │◄────────────────────────────────────┤
┌──────▼───────┐                             │
│ Data from    │                             │
│ Analytical   │                             │
│ Application  │                             │
└──────┬───────┘                             │
       │◄────────────────────────────────────┤
┌──────▼───────┐                             │
│ Hypothesis   │                             │
│ Testing      │                             │
└──────┬───────┘                             │
       │                            ┌────────▼─────────┐
┌──────▼───────┐                    │ The Routine      │
│ Report       │───────────────────►│ Planning Process │
│ Results      │                    └──────────────────┘
└──────────────┘
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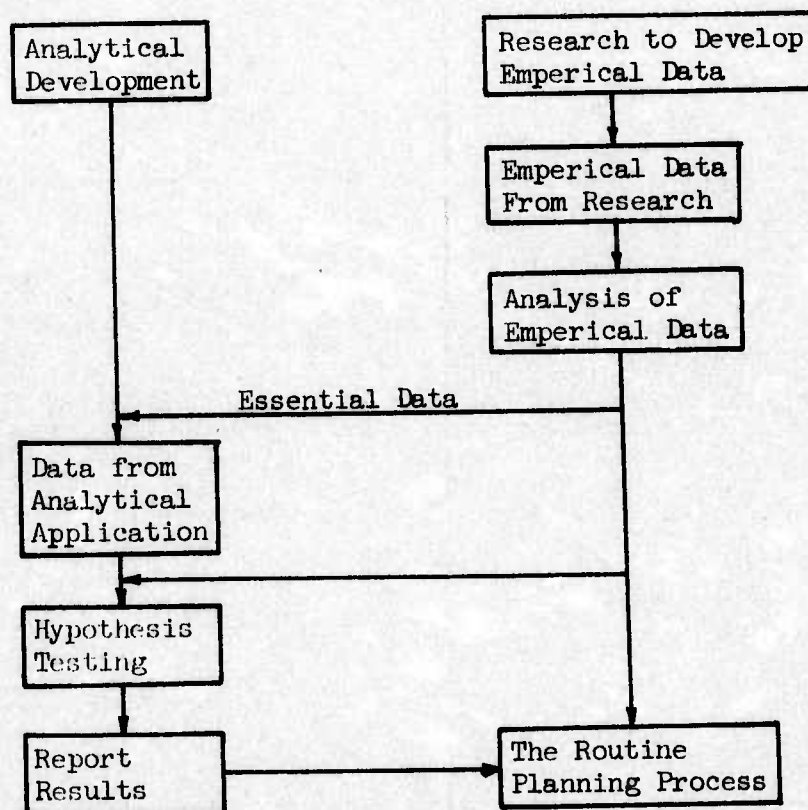
Figure 2.

Research Methodology

Analytical Aspects of the Hypothesis (Figure 3)

The hypothesis states:

For $0 \leq x \leq 1$, $\qquad y = (b - c) x + c.$ $\qquad\qquad$ (1)

That is, based on the assumption of linearity for the rate of ammunition expenditure for a force size from one weapon to a division, the ammunition consumption rate (y) is equal to the slope of the line (b - c), where b is a division rate, c is the single weapon rate, and a is the theater ammunition consumption rate.

For $1 \leq x$, $\qquad\qquad y = \dfrac{b - a}{x^n} + a$ $\qquad\qquad$ (2)

based on the assumption that the ammunition consumption rate (y) for
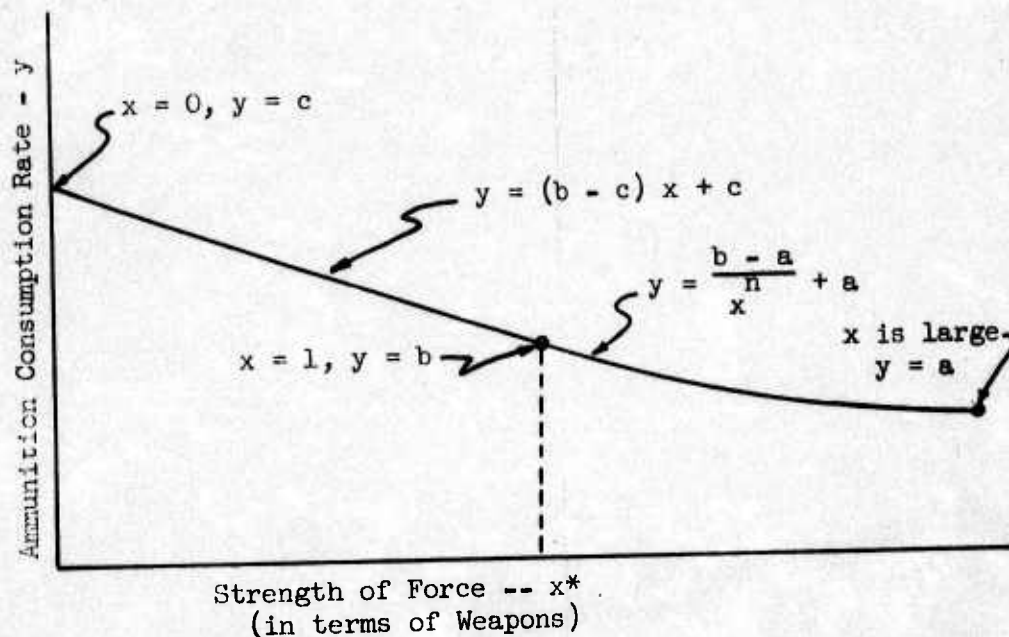
*x is a normalized representation of the number of weapons in the force. x = 1 for the weapons in a division.

Figure 3.

Ammunition Consumption Rate Vs
Strength of the Force

a force of division size or larger can be predicted by this relation-
ship where b is the division rate, c is the theater consumption rate
and x and n are as described on page 10. What remains is to determine
n in terms of a, b and c which will force equations (1) and (2) to
be tangent at x = 1. This can be done by equating slopes of
equations (1) and (2) at the point x = 1. The slope of equation (1)
is (b - c). We find the slope of equation (2) by taking the
derivative of equation (2) with respect to x, i.e.,

$$y = \frac{b - a}{x^n} + a \qquad (2)$$

$$\frac{dy}{dx} = -n(b - a)x^{-n-1} = -\frac{n(b - a)}{x^{n+1}} \qquad (3)$$

Equations (3) which is the slope of equation (2), and the slope of
equation (1) can be set equal at x = 1 since equations (1) and (2)
are tangent at that point. Thus,

$$\frac{-n(b - a)}{(1)^{n+1}} = b - c \qquad (4)$$

$$-n(b - a) = b - c \qquad (5)$$

$$n = \frac{b - c}{a - b} \qquad (6)$$

This value of n can be substituted in equation (2) to provide the
new equation

$$y = \frac{b - a}{x^{\frac{b-c}{a-b}}} + a \qquad (2')$$

Equation (1) and (2') can now be used to determine the ammunition
average consumption rates for any size force from a single weapon

to all the weapons in the theater given that values of a, b and c
are known. The question to be answered now is: given that for each
weapon of a particular type in a theater of operations a number of
rounds per weapon per day enter the logistics system of the theater
how many rounds per weapon per day can each weapon fire? Also, the
theater ammunition rate (a) is based on all the weapons of a given type
in the theater. How can any one of these weapons fire a greater
amount of ammunition per day than the theater rate? For any of
several reasons weapon availability to fire will seldom if ever reach
one hundred percent of the weapons in the theater. Among the reasons
for non-availability of the weapons are maintenance, movement for
position, movement for security, awaiting adjustment of fire which is
being accomplished by another weapon in the battery or other designated
firing element. Appendix C contains additional considerations on the
availability of artillery to fire in the discussion of the four-ninths
rule.

Essential Data

Equations (1) and (2') require that a, b and c be known values.
The value of a is the theater ammunition consumption rate provided in
SB 38-26. The value of c is the individual weapon rate and may be
drawn from FM 101-10-1. The value of b is the division average
ammunition consumption rate for the particular weapon being considered
under the given circumstances from which c is drawn. An appropriate
value of b must be determined through further research. The research
approach described below is intended to provide appropriate values of
b. An example of a candidate value of b for the 155mm howitzer is

67 rounds per weapon per day. This value has been drawn from Table 1
which has been extracted from the Operations Research Office Study[6]
on artillery use in WW II. The values in Table 1 for 155mm howitzers
must be divided by the number of weapons in the battalion (18) to
determine the average rate for a single weapon as it represents the
average of all the 155mm howitzers in the division.

Table 1.

AVERAGE ROUNDS PER DAY

Weapon	Rounds fired on day unit does not move		Rounds fired on day unit does move	
	Attack Phase	Movement Phase	Attack Phase	Movement Phase
155mm How				
Corps	1700	670	470	260
Divisional	1200	600	500	200

Data Development

The data used both to provide necessary and appropriate values
of b (the divisional ammunition consumption rate) and values for
other force sizes used for testing the hypothesis have been drawn
from a research project conducted by regular course CGSC students
under the direction of the author as well as from independent
research performed by the author. The student research project was
conducted specifically for the purpose of developing situationally
dependent planning factors for the new FM 101-10-1. The students'
research included historical data such as that contained in the
Operations Research Office studies [7,8,9] and the results of simula-
tions and war gaming efforts. The simulations providing data for this
research effort are discussed on page 3.

An example of data extracted from the Operations Research Office studies is contained in Table 1 and Appendix B. The data shown in Table 2 below was provided the author by the U.S. Army Concepts Analysis Agency (CAA). The data in Table 2 represents for the tanks and TOW and Dragon antitank missiles in a division the 24-hour expenditures in a high resolution combat simulation of a U.S. Army division against an enemy force considerably superior in strength to the U.S. Army force. The high resolution nature of the simulation means that rather than using a measure such as fire power potential of a weapon, e.g., a tank has ten (hypothetical) times the fire power potential of a TOW missile system, the simulation actually pits weapon against weapon and unit against unit in a simulated battle in a given location (terrain considerations) allowing maneuver and engagement to occur. The CAA data indicates for all the tanks in the division a divisional rate of 18.77 rounds per weapon per day. Considering only the M60A1 tanks the CAA data indicates a rate of 26.89 rounds per weapon per day considering the ammunition fired and the ammunition lost when tanks receive combat damage. Since the CAA simulation results are specifically representative of defensive operations, this data has been used to cause the author to select the curve shown in Figure 7, page 51, which results from the application of the thesis methodology, having a divisional rate of 25 rounds per weapon per day for the first day of defense under very heavy level of commitment, as representative of the 105mm tank gun ammunition consumption as a function of force size.

Table 2.

Divisional Ammunition Consumption Rates Per Weapon
Per Day from the U.S. Army Concepts Analysis
Agency's Theater Ammunition Rate Study
(Representative of a Heavy Level of Commitment)

Weapon System	Committed Weapons	Average Rds Fired Per Committed Weapon	Weapons Available	Average Rds Lost Not Fired	Average Rounds Consumed
XM1	21	14.65	31	0.52	11.44
M60A1 Tank	52	5.72	63	22.37	26.89
M60A3 Tank	93	7.78	126	10.75	16.51
All Tanks	166	8.06	220	12.73	18.77
TOW Missile	141	3.40	238	0.4	2.41
Dragon Missile	143	0.57	214	0.75	1.13

Other values of the divisional rate for the other weapons or

situations have been determined either in the same manner as described

above or by the application of a multiplying factor determined from

the ratio of the 1st day of defense to the succeeding days of defense

from the data contained in FM 101-10-1. For example, for the 105mm

tank gun FM 101-10-1 shows a 1st day of defense rate of 78 rounds

per weapon per day and a succeeding day rate is 60% of the 1st day

rate. This has led the author to choose a divisional rate (b) of 15

rounds per weapon per day for succeeding days of defense. The selec-

tion of this value of the division rate and applying the thesis

methodology has resulted in the selection of the curve shown in Figure

8, page 52.

Applying similar rationale to the 155mm howitzer considering

the available data, some of which is contained in Table 3, page 46,
and other which is contained in Appendix B, the following rates have
been selected as the division rates for a very heavy level of
commitment:

        1st Day of Attack - 100 rounds per weapon per day

        1st Day of Defense - 125 rounds per weapon per day

        Succeeding Days of Defense - 90 rounds per weapon per day.

      The author's selection of 3 rounds of TOW per TOW missile sys-
tem per day and 1.5 rounds of Dragon per Dragon tracker per day as the
division rates for TOW and Dragon for succeeding days of defense for
a very heavy level of commitment results from a combination of factors.
These factors include the CAA data from Table 2 for TOW and Dragon and
the data obtained by the author from the division wargame (DIVWAG)
simulation shown in Table 4, page 55, and the relationship between
the FM 101-10-1 rates and the division rates for the 105mm tank gun.
This relationship for the 105mm tank gun is that the division rate
for succeeding days of defense of 15 rounds per weapon per day is 32%
of the 47 rounds per weapon for the single weapon rate. Using 32% of
the single weapon rate, 10 rounds for TOW and 5 rounds for Dragon led
the author to select 3 rounds per TOW system per day and 1.5 rounds
of Dragon per Dragon tracker per day as the divisional rates for TOW
and Dragon. The selection of these rates is further supported by the
CAA TOW and Dragon rates shown in Table 2 of 2.41 and 1.13 rounds per
weapon per missile system per day respectively.

HYPOTHESIS TESTING

In testing the hypothesis the primary objective has been to determine if the results of the methodology proposed by the thesis provides reasonable estimates of ammunition requirements for a force of a given size considering single weapon ammunition consumption rates as provided in FM 101-10-1 and theater ammunition consumption rates as provided in SB 38-26. When a planner is forecasting ammunition requirements he is working in an area of such extreme uncertainty that for planning purposes he is seeking a reasonable start point for making his estimate. The characteristics of such a start point would insure that the ammunition requirements planned for would be enough to insure against both extreme shortages and overages until adequate experience has been gained to relieve a measure of the uncertainty that constantly plagues military planners. These thoughts have been kept in mind as the test of the hypothesis has been developed and carried out.

The ideal test of the hypothesis would be a statistically based test which would lead to the proper conclusion. In view of the data available to test the hypothesis, it is not feasible at this time to statistically test the hypothesis. In fact, if such a test could be made, then there would be no need for the methodology presented in this thesis and its attendent hypothesis because the true historical/ simulation based relationship of the ammunition requirements to force strength would be known.

An alternative to the statistically based test of the hypothesis is based on judgement. The approach that has been taken is closely akin to and can be termed a modification of the Delphi

procedure. Although desirable, sufficient time was not available nor
was it considered within the scope of this research effort to attempt
an extensive application of the Delphi procedure. As discussed in the
section above on data development, the results of the historical/simula-
tion based student research has provided insights on ammunition require-
ments as a function of the force size for some selected force strengths.
These results have been used along with the data the author has ob-
tained from CAA and DIVWAG to determine division rates.

One of the most easily recognizable proofs of the hypothesis
can be seen in the CAA data contained in Table 2. The division rate
of consuming 105mm tank gun ammunition is 18.77 rounds per weapon per
day. The data also shows that of 220 tanks available for the battle,
166 tanks actually became committed in the battle. This leads to
the conclusion that the ammunition consumption rate for the committed
tanks is 24.87 rounds per tank per day on the average. Using the
thesis methodology and assuming a divisional rate of 18.77 rounds
per weapon per day for the first day of a defensive action with the
single rate of 78 rounds per weapon per day from FM 101-10-1 and the
theater rate of 5.56 rounds per weapon per day from SB 38-26 leads to
the following value (y) for the 166 (220 times x) committed tanks:

$$a = 5.56, \quad b = 18.77, \quad \text{and } c = 78$$

$$y = (18.77 - 47) \frac{166}{220} + 47 = 25.23 \quad \text{rounds per}$$

committed tank per day on the average. The CAA simulation producing
the rates in Table 2 does not differentiate between the first and
succeeding days or a protracted period of combat. However, comparing
the thesis methodology results with the committed tanks result from

the CAA data we find:

105mm Tank Rounds Per Weapon Per Day

	CAA Committed Tanks	Thesis Methodology
First Day	24.87	33.58
Succeeding Days	24.87	25.23
Protracted Period	24.87	20.*

*This is the same rate as the protracted rate in FM 101-10-1 because when the single weapon rate from FM 101-10-1 falls below the divisional rate then the methodology requires the single weapon rate be used for all weapons in the division.

As can be seen in the comparison of results above the thesis methodology and the CAA results show excellent agreement for the succeeding days of combat and close agreement for the protracted period. These are considered the more significant because of the more general nature of these periods than the first day of the defense of a position. As would be expected under these circumstances, the thesis methodology provides a higher rate than the CAA results; however, the agreement between the two different numbers is such that the author is led to conclude that the CAA results support the author's argument thus further verifying the thesis methodology.

At this time the strength of the hypothesis and thus the validity of the methodology lies in the selection/determination of the divisional ammunition consumption rate for a weapon under consideration. It is the author's view that it is beyond the scope of this thesis to attempt to validate any rate used in the thesis or which

can be determined through the application of the thesis methodology. The author does have sufficient confidence in the rates provided in Chapter 4, Figures 4 through 10, results of the application of the thesis methodology, to use them as planning factors for determining ammunition requirements as a function of force size. This confidence is not easily conveyed to planners or commanders having a need for the type of data that can be provided by the thesis methodology. Statistical proofs, were there adequate statistical data upon which to base a statistical test would not be enough to convince planners and commanders to accept any rate that is provided. The necessary confidence comes from experience and serious consideration of the many faceted problem of determining ammunition requirements.

CHAPTER 3

FOOTNOTES

[1]U.S. Department of the Army, HQ, Department of the Army, Supply Bulletin, SB 38-26 (C).

[2]U.S. Department of the Army, HQ, Department of the Army, Field Manual, FM 101-10-1, July 1971, Table 5-21.

[3]FM 101-10-1, Table 5-21.

[4]Extracted from a personal conversation between the author and the quoted U.S. Army Colonel, January 1976.

[5]The U.S. Army Logistics Center, Fort Lee, Virginia, has recently proposed a change to the term available supply rate. The proposed change calls for the term controlled supply rate in the place of available supply rate. It is the author's view that the connotation of the new termanology is more correct than that carried by the term available supply rate.

[6]Duncan K. Love, Artillery Usage in World War II (U), Technical Memorandum ORO-T-375, April 1959, p. 126.

[7]Love, p. 65.

[8]Dorothy K. Clark, Ammunition Day of Supply, WW I to 1960, Technical Paper ORO-TP-18, December 1960, all pertinent tables.

[9]S. L. A. Marshall, Commentary on Infantry Operations and Weapons Usage in Korea, Winter of 1950-51, Report ORO-R-13, October 1951, all pertinent information.

"The main issue is need."

-Maj Gen Morris J. Brady-

CHAPTER 4

FINDINGS (ANALYSIS AND EVALUATION)

Due to the frequency of the application of the equations which constitute the methodology, the algorithm shown in Figure 2 below has been developed and programmed in the FORTRAN IV complier language. The FORTRAN program and a more detailed flow chart are shown in Appendix A. The computer program has been used to develop the ammunition consumption rate data contained in Appendix A. The selected curves resulting from the methodology are shown in Figures 4 through 9 below.

The findings presented here are based on a rather exhaustive analysis of both historical data and data resulting from combat simulations. The emphasis of the analysis by necessity, created by the plethora of data on artillery weapons and the dearth of information on other weapons considered in this research, is centered around the 155mm howitzer. Results of the analysis are also presented for 105mm tank gun, and TOW and Dragon antitank missiles. Due to the lack of both historical data and simulation results, these weapons consumption rate curves could not be validated to the same degree of certainty as the 155mm howitzer. As can be seen in Appendix B, the methodology generates a great deal of data for consideration and graphical portrayal. The problem now becomes one of selection of the graph that properly presents the relationship between force size and ammunition consumption. The graphs shown in Figures 4 through 10 which are

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START

INITIALIZE PROGRAM
WITH INPUT DATA:
KNOWN RATES AND
SITUATION (A, B, C)

COMPUTE THE NUMBER
OF WEAPONS FOR
WHICH RATE OF FIRE
IS TO BE DETERMINED

1

DETERMINE THE RATE
OF FIRE USING
METHODOLOGY, I.E.,

$y = (b-c)x + c$
  if $0 \leq x \leq 1$
  and
$y = \dfrac{b - a}{x^n} + a$

  if $1 \leq x$

PRINT THE RE-
SULTING
RATES

IF MORE RATES ARE
REQUIRED RETURN TO
START OTHERWISE
STOP
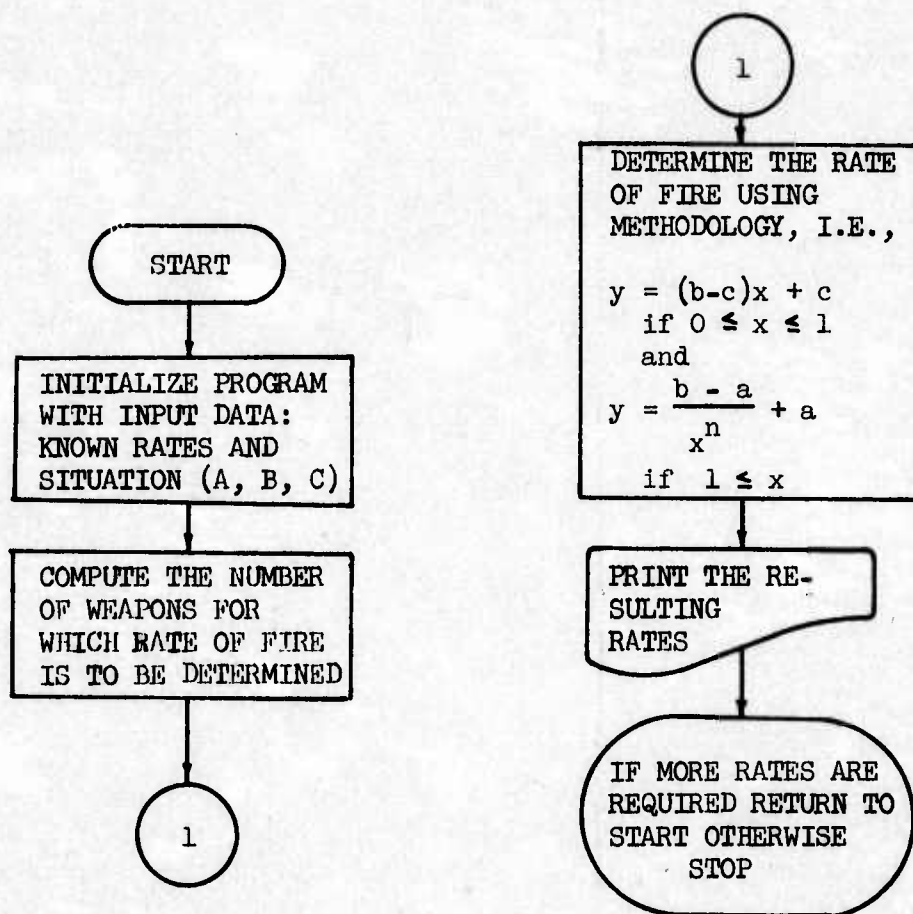
A = Theater Rate, B = Division Rate, C = Single Weapon Rate

results of the application of the thesis developed methodology, i.e.,
the graphs which have resulted from the stated hypothesis, are
considered to be adequately accurate representations of ammunition
consumption as a function of force size. Consequently these curves
may be used for and considered valid for prediction of ammunition
requirements as a function of force size. For the 155mm howitzer the
basis for this statement in addition to the application of the author's
judgement is the comparative analysis presented in Table 3. As can be
seen from the analysis presented in Table 3, there is relatively close
agreement between the historical data and the rates predicted by

the methodology.

An inquirer is rightfully led to ask at this point, "Okay, so your methodology predicts history pretty well, what can it do for me when I want to know future requirements?" The question is certainly valid but it should be recognized in answering it that any methodology such as the one presented here must first agree with history before it can be accepted for the prediction of future requirements. The comparison in Chapter 3 of the methodology results with the CAA results for the 105mm tank gun has to some extent given an indication of the methodology's ability to predict future requirements as CAA's Theater Ammorates study primarily looks at future requirements. To use methodology to predict future requirements, there are several considerations.

Table 3. 155mm Howitzer Rounds per Weapon per Day,
1st Day of Attack, Heavy Level of Commitment

No. of Weapons	Thesis Method Select Curve [1]	Historical Example [2]	Statistical Representation of Historical Examples [3]	Simulation Results [4]	Four Ninths Rule	Modified Four-Ninths Rule
1 Wpn	192	-	-	-	-	192
1 Div 54 Wpn	100	78	59	89	85	168
2 Div 108 Wpn	66	78	59	89	85	142
3 Div 108 Wpn	59	78	59	89	85	119

Notes:
1. Based on a theater rate (a=54), a division rate (b=100), and a single weapon rate (c=192).
2. Attack of Utah Beach, 6 June 1944 (1 day).
3. At a .99 or 99% confidence level.
4. U.S. Army Concepts Analysis Agency AMMORATES Study P78-82.

These considerations include the availability of or availability to produce ammunition for which the use can be planned. This thought may seem rather simplistic at first glance; however, there is more here than meets the eye and further it is worth mentioning. A planner may consider that needs can be met if the division which he is planning for can be provided 75 rounds of 155mm howitzer ammunition per weapon in the force per day. For a five division corps made up of mechanized and armored divisions, the planner, making an assumption that every weapon would need 75 rounds per weapon per day would say the divisional 155mm howitzers of the corps will require 18,625 rounds per day. The employment of the method presented here indicated that 75 rounds per weapon can be met if the corps is provided 14,750 rounds per day. This represents a rate of 54 rounds per weapon per day considering all the 155mm howitzers in the division. When viewed by the division consider-ing the 54 155mm howitzers in the division this would represent 75 rounds per weapon per day for the weapons firing. The validity of this figure for planning purposes is further demonstrated by the four-ninths rule which provides the results that the required 75 rounds per day can be provided by a corps rate of 33 rounds per weapon per day. Additionally the modified four-ninths rule provides the result that if the corps is provided an average rate of 54 rounds per weapon then the division will have 62 rounds per weapon to be fired by each weapon available to fire. The "four-ninths" and "modified four-ninths" rules are discussed in Appendix C.

The graphs shown in Figures 7 and 8 have been chosen as being representative of the firing rate force strength relationship for the 105mm gun mounted on the M60 series tanks. The selection of these
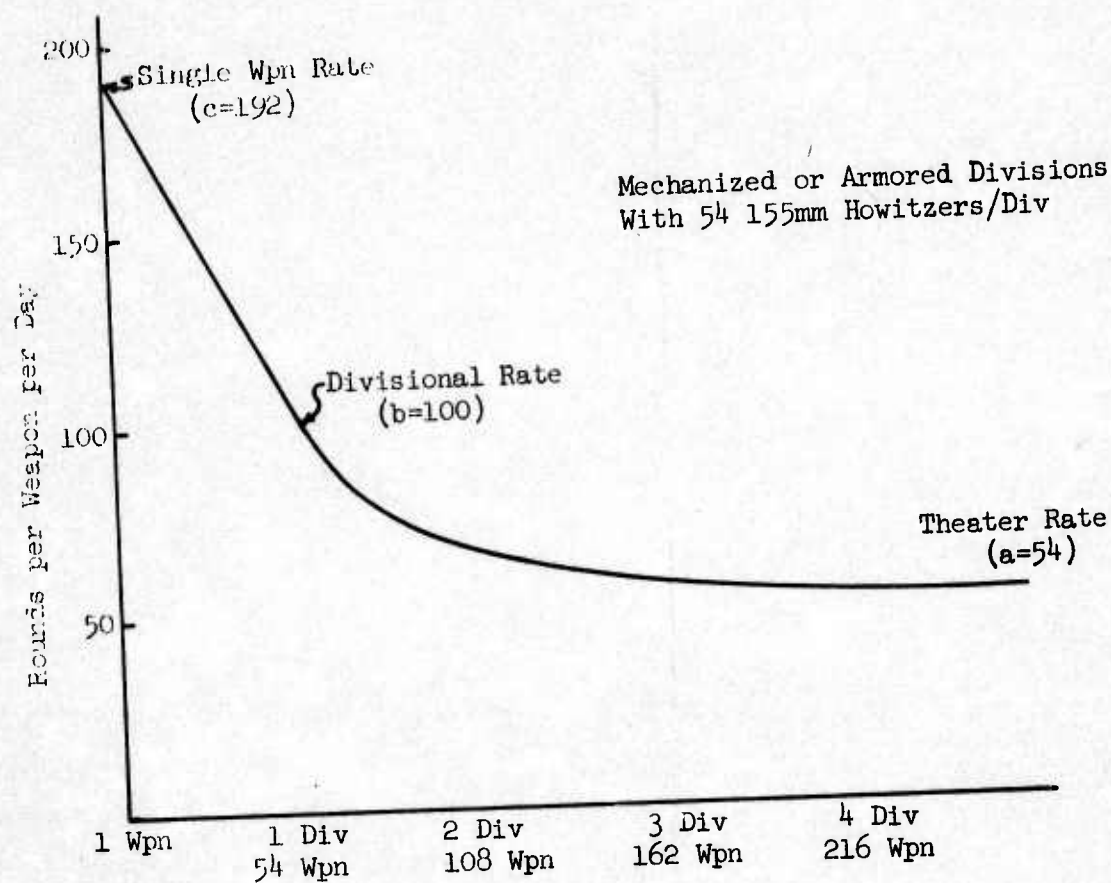
Figure 4.   155mm Howitzer Rounds per Weapon per Day, 1st Day of Attack, Heavy Level of Commitment, Based on Thesis Methodology
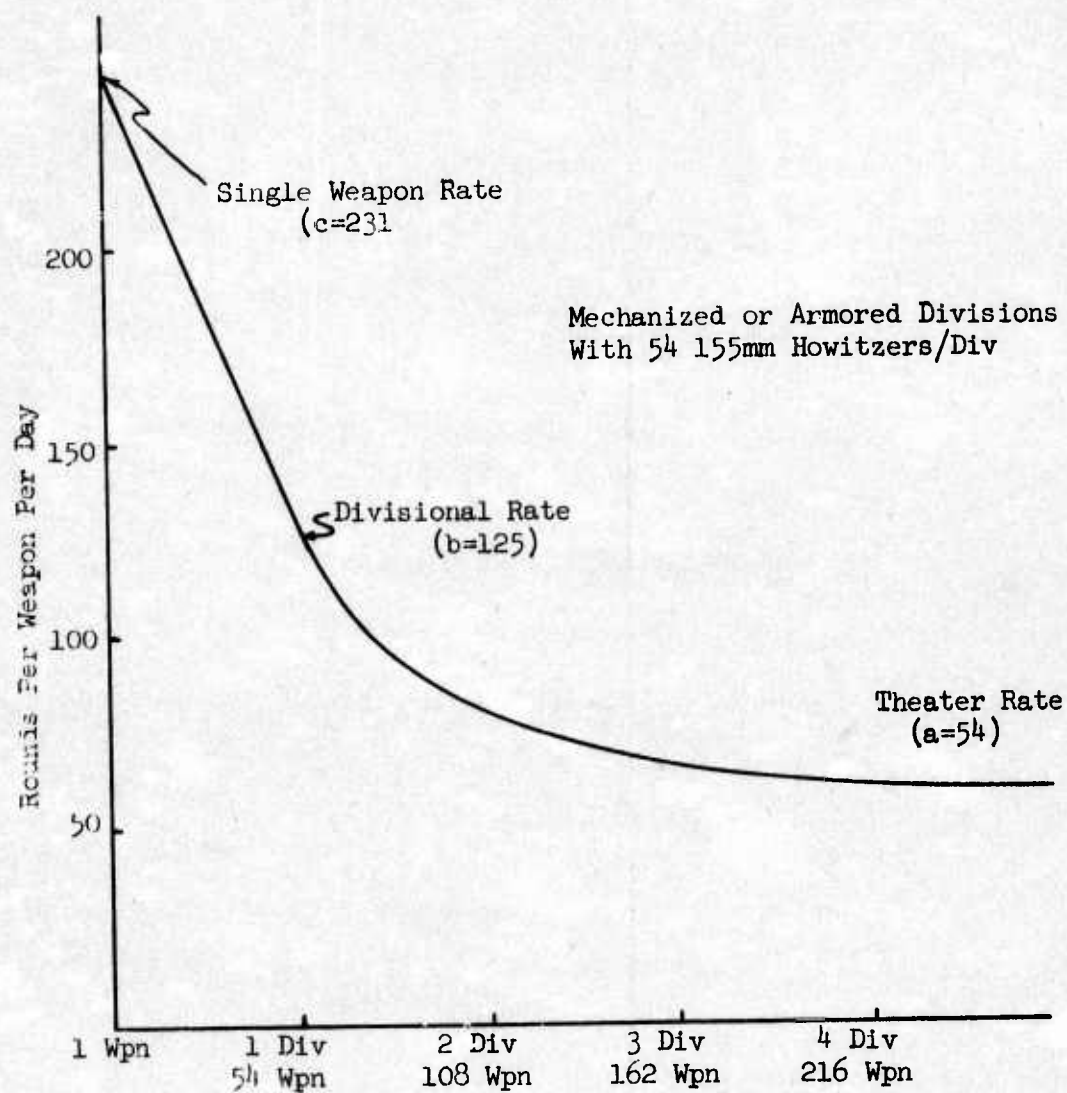
Figure 5. 155mm Howitzer Rounds per Weapon per Day,
1st Day of Defense, Heavy Level of
Commitment, Based on Thesis Methodology
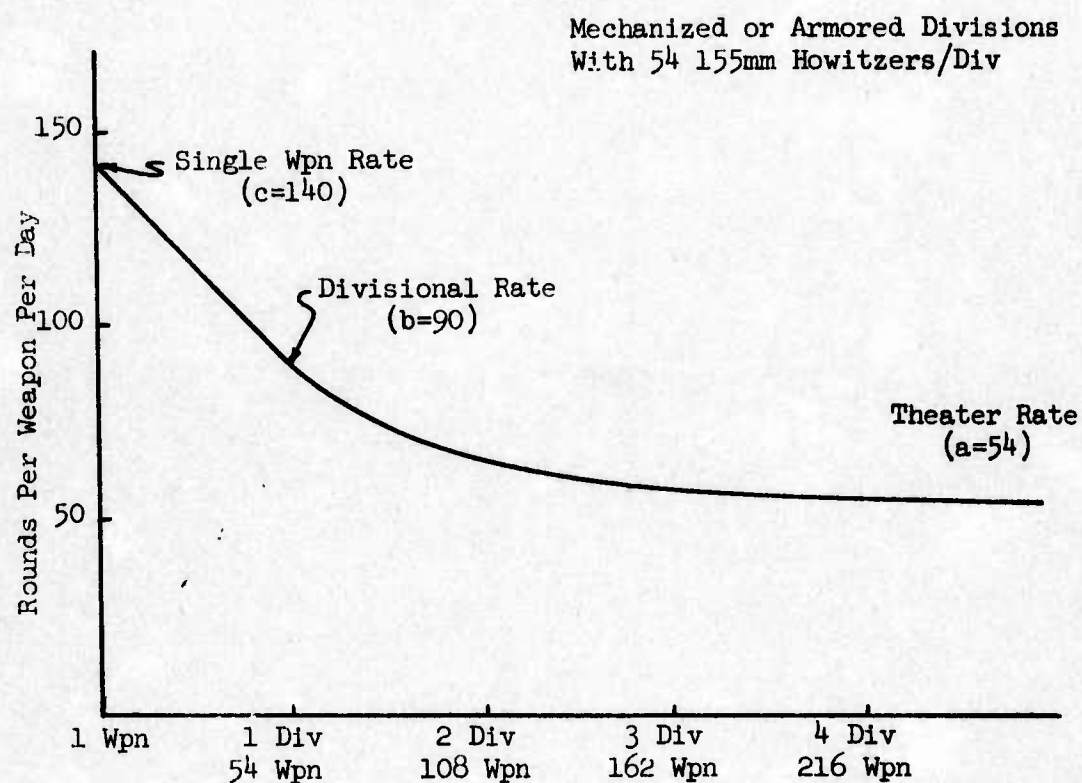
Figure 6. 155mm Howitzer Rounds per Weapon per Day, Succeeding Days of Defense, Heavy Level of Commitment, Based on Thesis Methodology
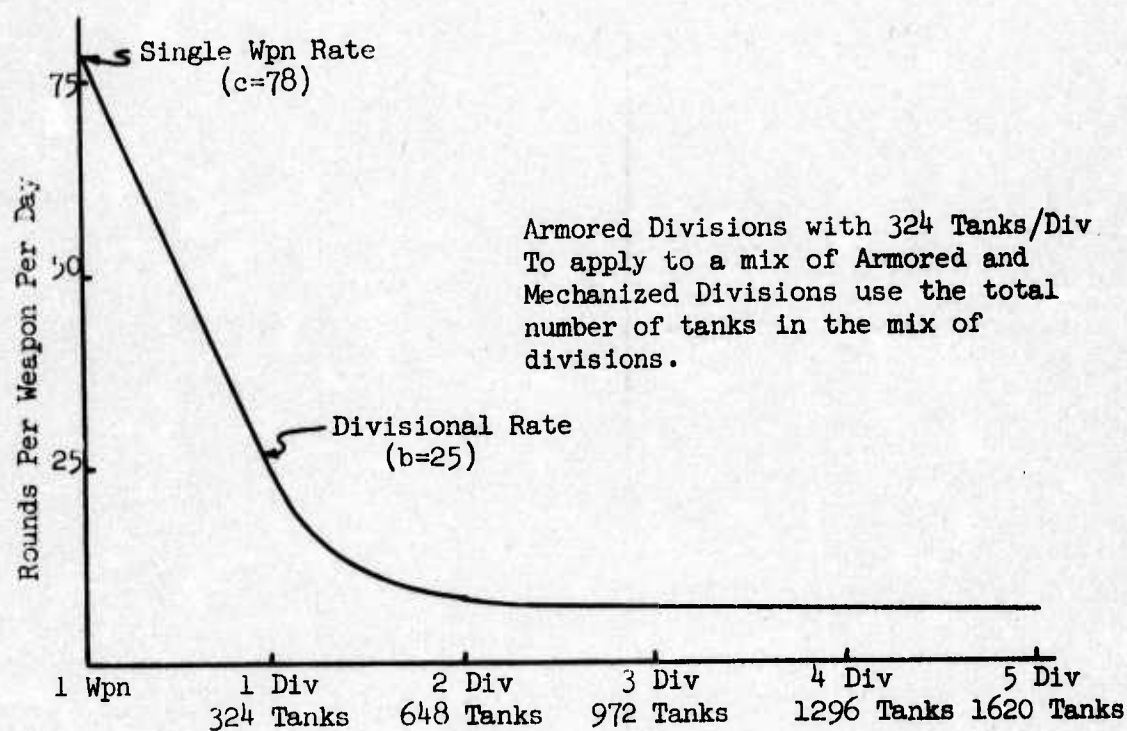
Figure 7. 105mm Tank Guns Rounds per Weapon per Day,
1st Day of Defense, Very Heavy Level of
Commitment, Based on Thesis Methodology

Armored Divisions with 324 Tanks/Div
To apply to a mix of Armored and
Mechanized Divisions use the total
number of tanks in the mix of
divisions.
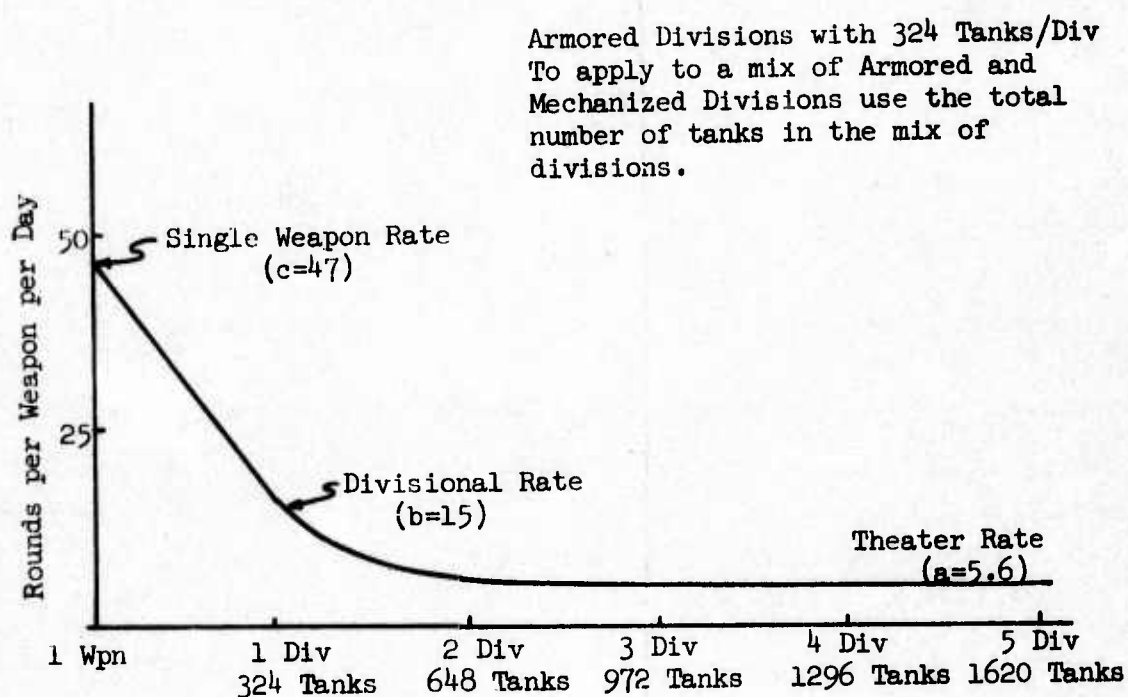
Figure 8.   105mm Tank Guns Rounds per Weapon per Day,
Succeeding Days of Defense, Very Heavy Level
of Commitment, Based on Thesis Methodology.

particular curves is based on experience in the 1973 Middle East War
in the employment of M60A1 tanks with 105mm guns and results of
combat simulation. During the 1973 War, the Isralis average firing
rate for all tanks mounting a 105mm gun was between five and ten
rounds. There were instances reported where some tanks fired more than
30 rounds in a day. One of the most definitive instances reported[1]
was that the average number of rounds fired by the tanks of a company
fighting in the Golan Heights was 15 rounds per tank per day for a
10 day period. The theater rate of 5.6 rounds is drawn from SB 38-26
and was developed by the Concepts Analysis Agency in its AMMORATES
Study. The single weapon firing rates have been drawn from FM 101-10-1.
Appendix B contains tabular data resulting from the use of the thesis
methodology.

The graphs shown in Figure 9 and 10 below have been chosen as
valid representations of the firing rate force strength relationship
for the TOW and Dragon antitank missile systems. The selection of
these particular curves is based primarily on the results of combat
simulations. Although there was some application of TOW missiles in
combat in Vietnam during 1972 and 1973 this application was in the
helicopter mounted role and as such not readily equatable to the
ground role considered here. The research did not discover any rates
of fire of antitank missiles such as the SAGGER employed by the Egyptian
and Syrian forces during the 1973 Mid East War which could be used as
part of a comparative analysis here.

The combat simulations which led to the selection of the
curves shown in Figures 9 and 10 are the Division Wargame (DIVWAG)
and the AMMORATES Study. As a result of forty tank and mechanized

battalion task force hours of combat simulation of the first day of a defensive action under a very heavy level of commitment, the average firing rate for TOW and Dragon were found to be 0.52 and 0.24 rounds per weapon per hour respectively. The forty hours of battalion task force combat took place during six hours of mechanized division combat. Realizing the danger in doing so, the 0.52 and 0.24 rounds per hour have been extrapolated to a daily rate of 16 rounds of TOW and 6 rounds of Dragon per tracker per day for the first day of defense under a very heavy level of commitment. The firing rates for TOW and Dragon resulting from DIVWAG and the application of the definitions of level of commitment are shown in Table 4.

As a rough indication of the amount of planning data, the methodology can produce for the planner each entry in Table 4 could be used to produce graphs such as those shown in Figures 4 through 10 or tabular data such as that in Appendix B for developing ammunition requirements as a function of force size. It is well recognized that the data provided by the methodology presented here is no better than the source, however, if the planner recognizes the potential wide variation in requirements as viewed from different levels of the force an underlying objective of this thesis is met.

Table 4. Rounds per Weapon per Day for
TOW and Dragon Antitank Missile Systems
Based on the Division Wargame (DIVWAG)
Simulation

Level of Commitment	Defense of Position		Attack of Position			
	1st Day	Succeeding Days	1st Day	Succeeding Days	Protracted Period	Reserve
TOW						
Heavy	13	8	11	6	3	0.5
Moderate	7	5	6	3	2	0.3
Light	2	2	2	1	1	0.2
Dragon						
Heavy	5	3	4	2	1	0.17
Moderate	3	2	2	1	0.7	0.12
Light	1	1	1	0.5	0.3	0.05
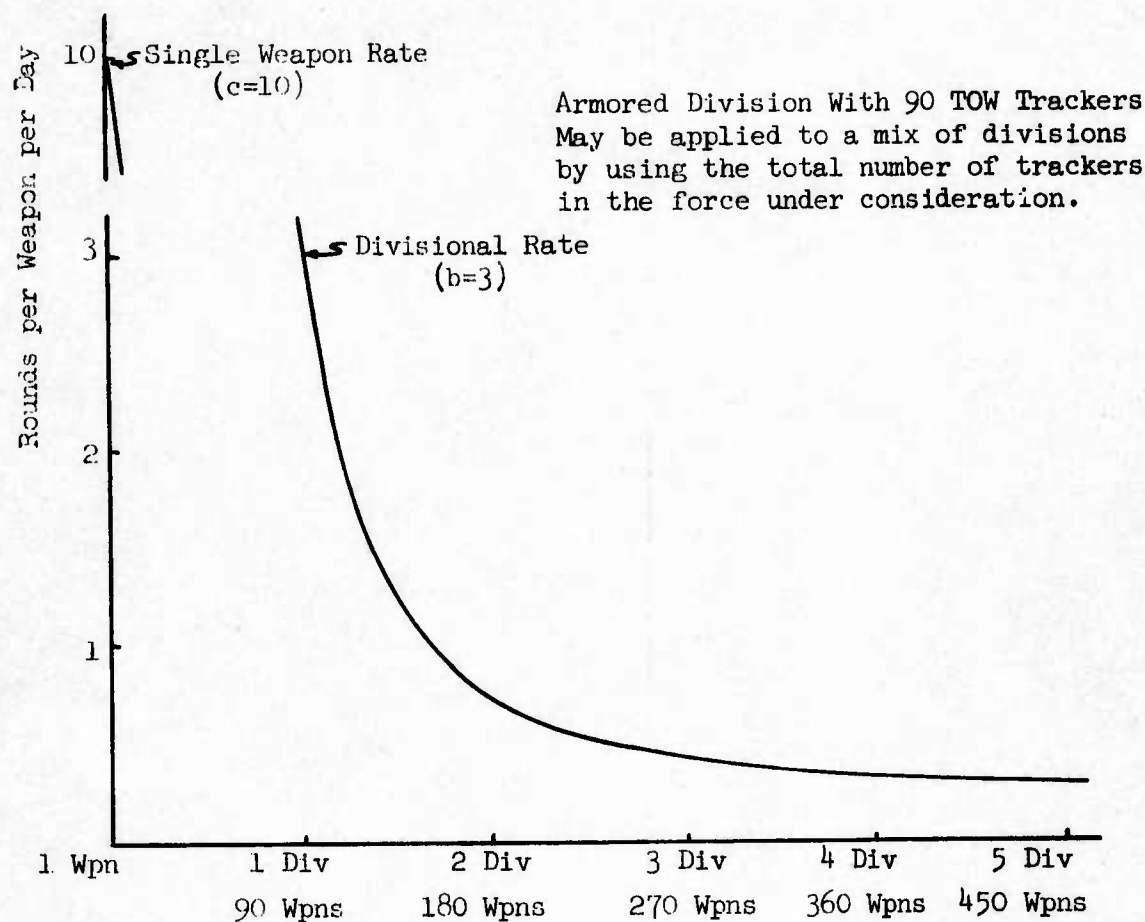
Figure 9. TOW Antitank Missile Systems, Rounds per Tracker per Day, Succeeding Days of Defense, Very Heavy Commitment based on Thesis Methodology.
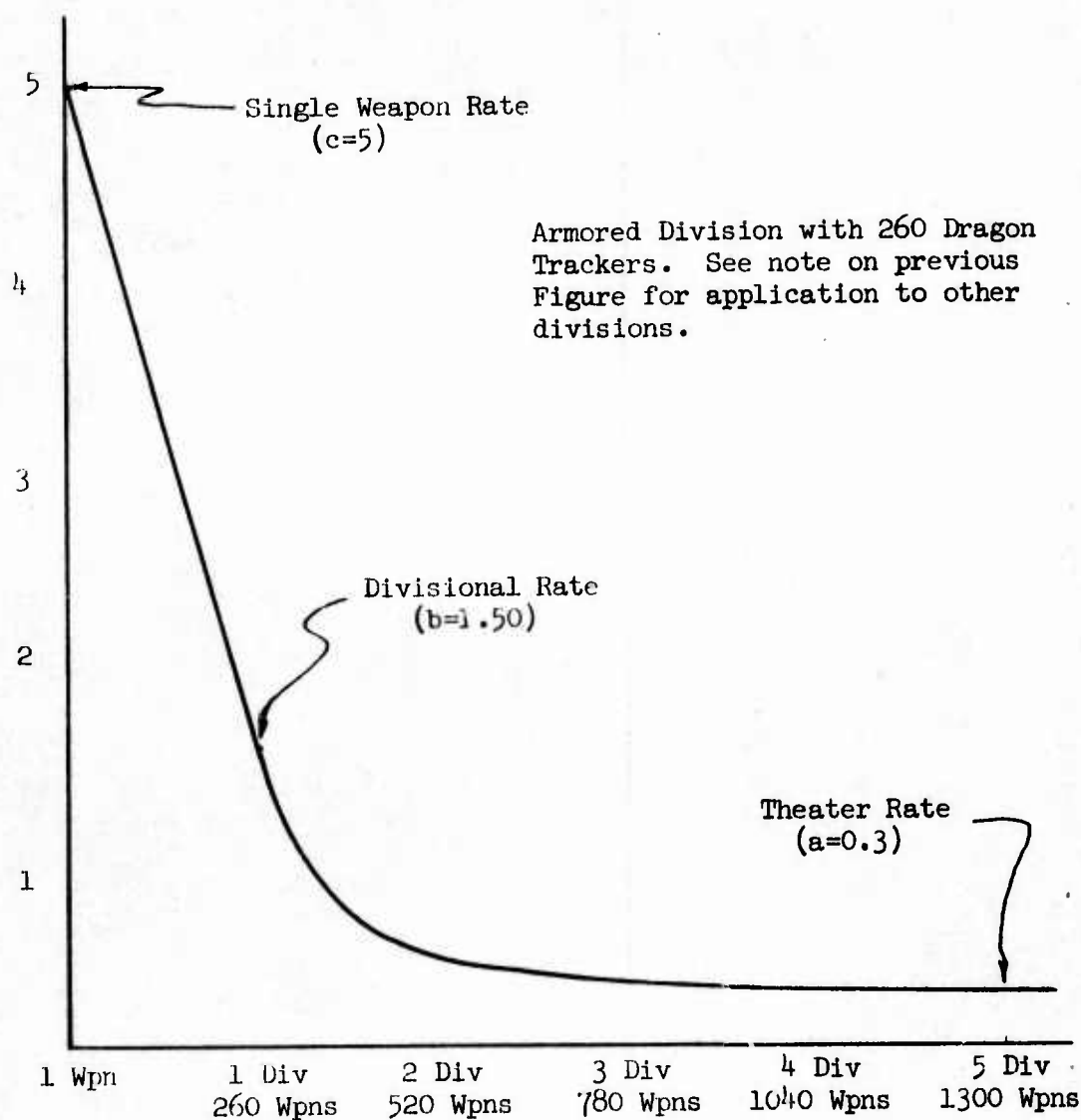
Figure 10. Dragon Antitank Missile, Rounds per Tracker
per Day, Succeeding Days of Defense, Very
Heavy Commitment Based on Thesis Methodology

CHAPTER 4

FOOTNOTES

[1]S.L.A. Marshall, <u>Tank Warrior in the Golan</u>, Military
Review, January 1976.

SUMMARY, CONCLUSIONS, RECOMMENDATIONS

SUMMARY

Problem

As we pass through a period of abundant and in some cases excess resources to one of just enough to get by and even perhaps one when only minimum essential necessities can be met, we must continually take a look at our planning procedures, factors, and assumptions. This thesis has taken a look at one of the many problems facing planners in an attempt to provide a greater insight into the nature of the problem and a possible alternative to solving the problem. The problem being the relationship of ammunition consumption to force size. As has been demonstrated and discussed, there are many highly sophisticated combat simulations which provide predictions as to ammunition requirements. This thesis is not an attempt to add another to the list. In fact, the methodology is an attempt to reduce the problem to one which is easily understood and reasonably solvable with the tools a planner normally has at hand without an extensive analytical treatment.

Methodology

The methodology does not nor is it intended to provide a panecea to the ammunition planner. This methodology addresses only one aspect of the planners problem and that is force size. As has previously been discussed in Chapter 1, (page 9) there are many significant factors which determine the ammunition requirements and which the methodology

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proposed here does not explicitly address. Major among these factors
are the effects of time and all its attendent implications which
include the ability to resupply when needed (distribution) and the
ability to fire when targets are available (tactics) and the nature of
the enemy force or the threat the enemy poses. Each of the significant
factors is just as important if not more so than force size alone and
must be addressed by ammunition planners if their estimates of the
ammunition needs of their force are to reflect true requirements.
This is not an apology for the inadequacies of this methodology which
admittedly are many, but it is just another attempt to place this many
faceted problem in proper perspective so that the most accurate esti-
mate possible can be made.

Results

The value or validity of the ammunition consumption rates
provided by this methodology should be challenged by any potential
user. This does not mean that any given rate or set of rates for any
given weapon or set of weapons is not one hundred percent correct.
This only means that due to the uncertainty, i.e., the inability to
foresee what will actually occur, associated with each given rate,
a wide range of variations can occur. The responsibility for the
most accurate determination possible of the true need still rests with
the appropriate commander with staff responsibility delegated to his
J3/G3 or S3. The results of this thesis can do little more than
assist in developing a greater degree of understanding by the officer
responsible for requirements determination as to the true nature of
the problem that faces him. If this greater degree of insight has
resulted then the purpose of the thesis has been achieved.

CONCLUSIONS

    As stated in Chapter 1, the purpose of this research effort has been to develop a methodology which will provide ammunition consumption rate planning factors for planners developing estimated ammunition requirements for operations below theater level. As evidenced by the data displayed in Chapter 4 and the provision of the computer program which can be used to develop data of the same type for other weapons systems, it is the conclusion of this researcher that the purpose has been achieved. Does this mean that the problem of predicting ammunition requirements for operations below theater level is now solved for the planner? The answer, of course, is an unequivocal "no". There are two reasons for this, one being that this was not the intended purpose and the second and most important being the problem can only be solved at the proper time and the proper place by the proper planner as applies to the specific problem posed to the planner at that time. It goes back to the old and well-worn cliche, "It all depends on the situation." But now and as a result of this research, the old cliche should begin to take on a very serious position in the planner's thinking and on his thought as he thinks through the problem. If the reader has been stimulated by this effort to think more seriously about planning toward more accurately predicting requirements, then a second, unstated, more pervasive and perhaps more important purpose has been achieved. Of course, it is anticipated that a planner, having read this thesis and grasped the main idea will be better prepared to accomplish his planning tasks.

    In a recent paper[1] prepared by the U.S. Army Chief of Staff,

General Fred C. Weyand and Lieutenant Colonel Harry G. Summers, Jr.,
the statement was made, "Requirements must be justified on their own
merits, and not only the President but the entire Congress must be
convinced, as well as the American people whom the Congress represents."
If the reader asks, "Well that's nice but what has that got to do with
predicting ammunition requirements as a function of force size?",
then a lack of understanding is evidenced because that has everything
to do with the problem. It is not desired to deprive any soldier,
unit, organization, or force that what it needs to do the job assigned.
Yet at the same time we have no resources to waste, we cannot afford
the surpluses we have allowed in the past and we must to the best of
our ability accurately predict our requirements. If we are not able to
do this, then we will not be able to convince the President, Congress,
and the people of our needs and the necessity to provide funds for
our requirements.

RECOMMENDATIONS

Many assumptions are made every time a military planner sets out
to develop a possible course of action. One such assumption that has
been commonly made is that consumption of ammunition is uniform over any
given force. We have even gone so far in this assumption as to provide
the planner a number of pounds per man per day of ammunition. Intuitive-
ly, one feels that this assumption can serve a purpose only in the
grossest of estimates and every effort should be made to try and
refine such an estimate. This research has addressed this assumption
and in doing so it only lays bare other assumptions that should be
subjected to further analysis. One such assumption is that ammunition

requirements generally decrease with time, i.e., initial requirements, e.g., the 1st days requirements, are greater than requirements sometime in the future. Another assumption is that in general all weapons require more ammunition in defensive operations than offensive operations. These assumptions may be valid, however, it is recommended that this research provide a start point for challenging gross assumptions that the ammunition planner is required to make. Additionally, it is recommended that ammunition planners use the information provided here to challenge any previous or future plans which have begun or will begin with an assumption of uniform ammunition consumption for a force of battalion size or greater.

CHAPTER 5

FOOTNOTES

[1] General Fred C. Weyand and Lieutenant C lonel Harry G. Summers, Jr., Serving the People - The Need for Military Power, Directorate for Freedom of Information and Security Review (OASD-PA), Department of Defense, January 1976, p. 4.

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APPENDIX A

Flow Chart and FORTRAN IV Computer
Program for Thesis Methodology

Flow Chart of Program Designed to Compute
Ammunition Consumption as a Function of Force Size
Based On Thesis Developed Methodology

Flow Chart (Cont'd)

②

③

$x = 0$
$y = c$

More Data

—Yes→ START

—No→ STOP

Write:
b, y

$x = x + 1$
$y = b$

$y = \dfrac{b - a}{x^n} + a$

Write:
y

$x = x + 0.25$

$1 \leqslant x \leqslant 2$ —Yes→

—No→ $x = x + 1$ → $x > 5$ —No→

—Yes→

⑤
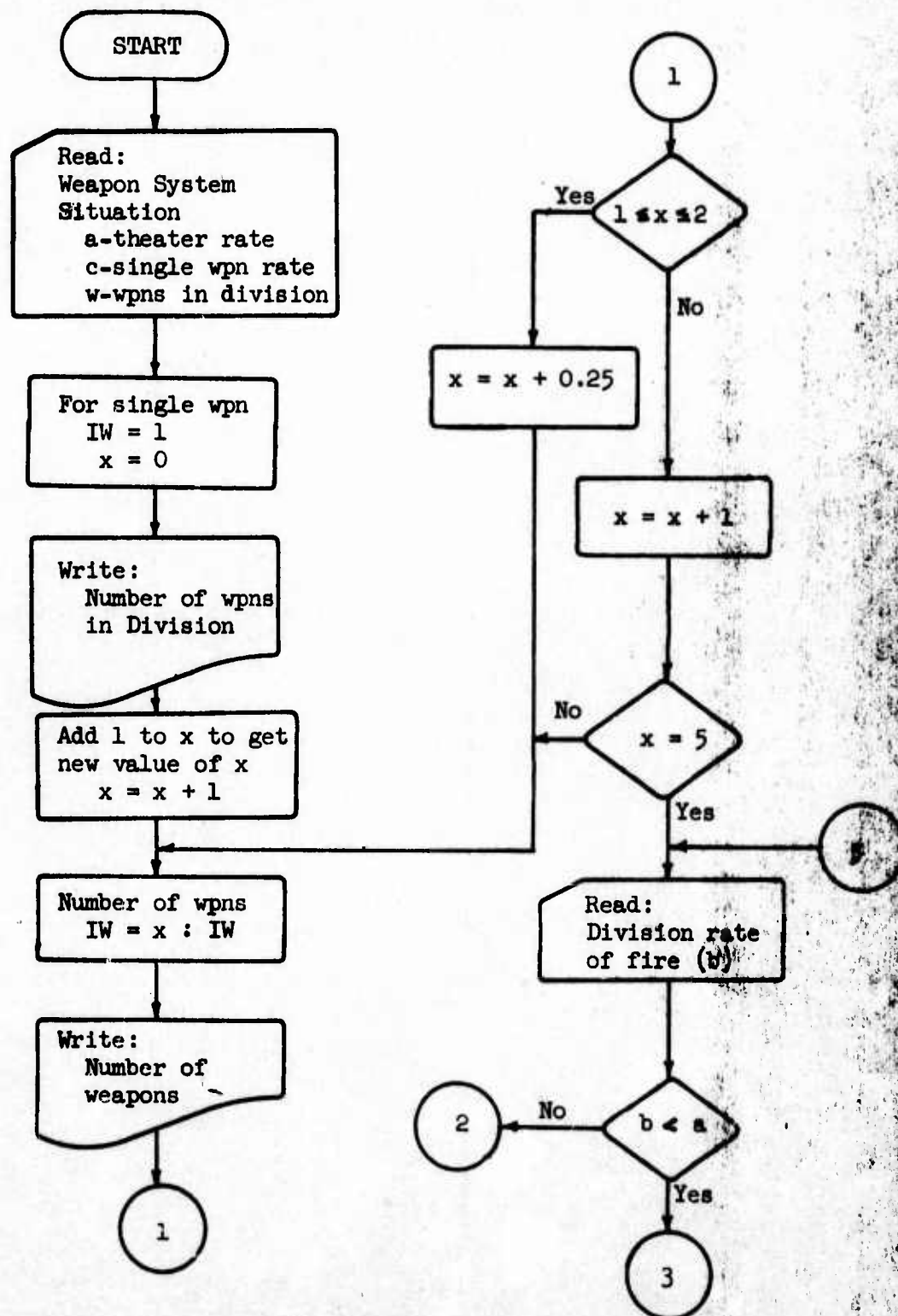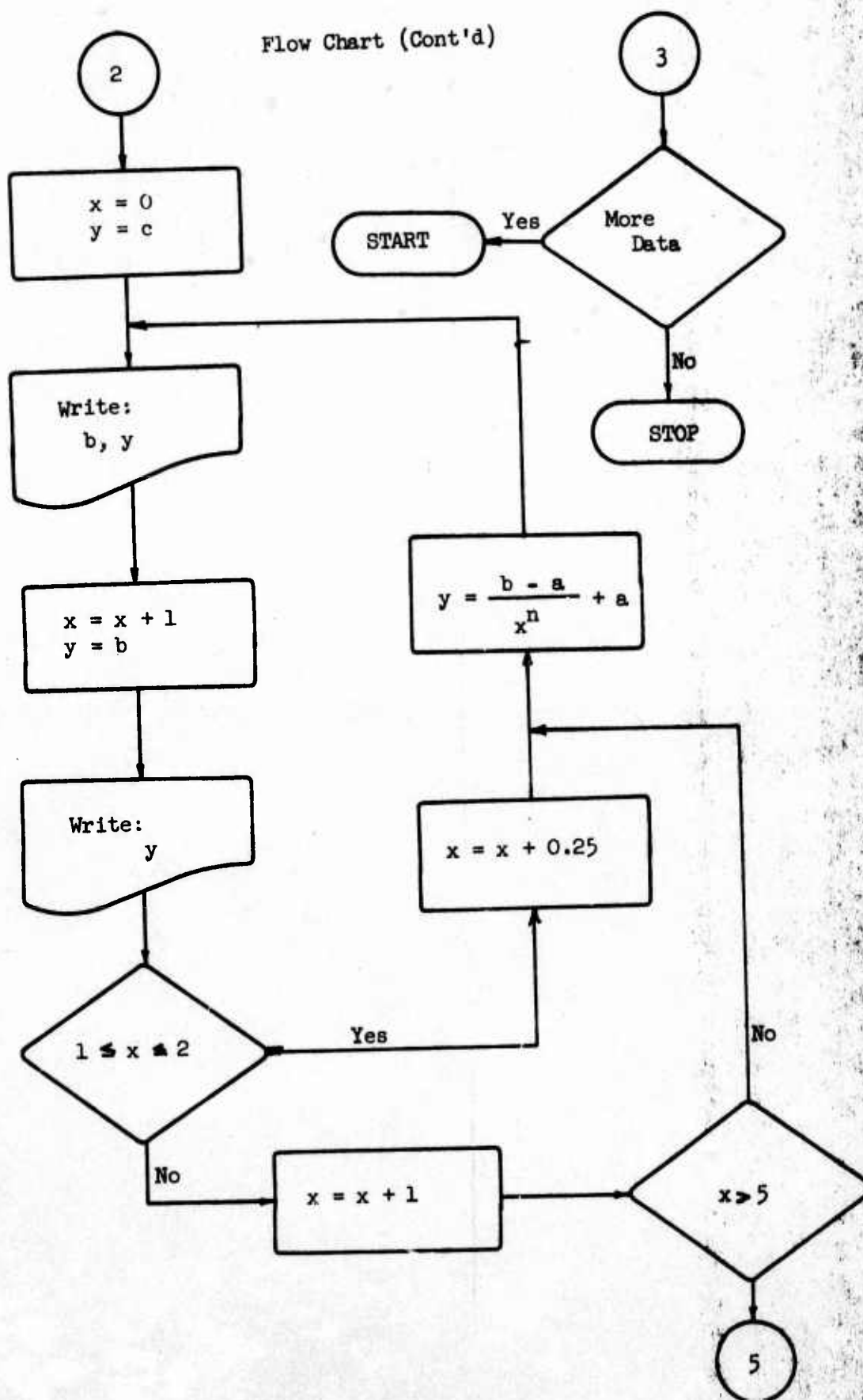
FORTRAN IV Program for Computing Ammunition
Consumption Rates as a Function of Force Size
Based on Thesis Developed Methodology

```
        PROGRAM TEST (INPUT,OUTPUT)
        DIMENSION IWPN(8)
        DIMENSION Y(8)

C  READ AND PRINT PAGE HEADING INFORMATION

        PRINT 101
101     FORMAT (T10,"AMMUNITION IN ROUNDS PER WEAPON PER DAY)
C  READ AND PRINT WEAPON SYSTEM
        PRINT 102
102     FORMAT (T5,"WEAPON SYSTEM")
201     READ 105,WEAP
105     FORMAT (A3)
        IF (WEAP.EQ.3HEND) GO TO 999
C  READ AND PRINT SITUATION
        PRINT 110
110 FORMAT (T5,"SITUATION")
        READ 105,WEAP
C  INITIALIZE WEAPON COUNTER BY PROVIDING THE NUMBER OF
C  WEAPONS IN THE DIVISION
111     FORMAT (T5,"WEAPONS IN DIVISION")
        READ 101,IDW
107     FORMAT (A3)
C  READ AND PRINT COLUMN HEADINGS - VALUES OF X
        PRINT 112
112     FORMAT ("VALUE OF X",T13,"X=0.00",T20,"X-1.00",T27,
       *"X=1.25",T34,"X=1.50",T41,"X=1.75",T48,"X=2.00",T55,
       *"X=3.00",T62,"X=4.00")
C  COMPUTE THE NUMBER OF WEAPONS
        X=0
        IWPN(1)=1
        IWPN(2)=IDW
        IWPN(3)=IDW*1.25
        IWPN(4)=IDW*1.5
        IWPN(5)=IDW*1.75
        IWPN(6)=IDW*2
        IWPN(7)=IDW*3
        IWPN(8)=IDW*4
C  PRINT VALUES OF NUMBER OF WEAPONS
        PRINT 108,IWPN
108     FORMAT ("NUMBER OF WEAPONS",T5,816)
C  PRINT HEADING OF LEFT COLUMN
        PRINT 109
109     FORMAT ("DIV     THTR     SING"/"CONS     CONS
        "RATE     RATE     RATE")
```

FORTRAN IV Program (Continued)

```
C  READ DIVISION FIRING RATE, THEATER RATE AND SINGLE WPN RATE
200       READ 110, B,A,C
110       FORMAT (R4,2AB)
          IF (B.EQ,0) GO TO 201
C  COMPUTE FIRING RATE (Y) FOR VARIOUS VALUES OF X
C  INITIALIZE RATE COUNTER
          Y(1)=C
          X=1
          Y(2)=B
          DO 111 I=3.6
          X=X+0.25
111       Y(I)=(B-A)/(X**((B-C)/(A-B))+A
          DO 112 I=7,8
          X=X+1
112       Y(I)=(B-A)/(X**((B-C)/(A-B))+A
          PRINT 113 Y(I) I=1,8
113       FORMAT (T23,8F6)
          GO TO 200
999       STOP
```

APPENDIX B

Data

Table B1. Ammunition in Rounds per Weapon per Day

Thesis Methodology Results - 155mm Howitzer
Armored or Mechanized Division - 1st Day of Attack
Heavy Level of Commitment

Weapons in Division - 54

Theater Rate - 54 rds/wpn/day (SB 38-26)

Single Weapon Rate - 192 rds/wpn/day (FM 101-10-1)

Value of x	x=0.0	x=1.0	x=1.25	x=1.5	x=1.75	x=2	x=3	x=4
No. of Wpns	1	54	67	81	94	108	162	216
Divisional Rate								
67	192	67	56	54	54	54	54	54
80	192	80	64	59	56	55	54	54
100	192	100	83	74	69	66	59	57
120	192	120	106	96	90	85	74	69
140	192	140	129	121	115	110	98	91

Table B2.   Ammunition in Rounds per Weapon per Day

Thesis Methodology Results - 155mm Howitzer
Armored or Mechanized Division - Succeeding Days of Attack
Heavy Level of Commitment

Weapons in Division - 54

Theater Rate - 54 rds/wpn/day (SB 38-26)

Single Weapon Rate - 105 rds/wpn/day (FM 101-10-1)

Value of x	x=0.0	x=1.0	x=1.25	x=1.5	x=1.75	x=2	x=3	x=4
No. of Wpns	1	54	67	81	94	108	162	216

Divisional Rate

55	105	55	54	54	54	54	54	54
60	105	60	55	54	54	54	54	54
65	105	65	59	57	55	55	54	54
70	105	70	64	61	59	58	55	55
75	105	75	69	66	63	62	58	57
80	105	80	75	72	69	67	63	61
85	105	85	81	78	76	74	69	67
90	105	90	87	84	83	81	77	74

Table B3. Ammunition in Rounds per Weapon per Day

Thesis Methodology Results - 155mm Howitzer
Armored or Mechanized Division - 1st Day of Defense
Heavy Level of Commitment

Weapons in Division - 54

Theater Rate - 54 rds/wpn/day (SB38-26)

Single Weapon Rate - 231 rds/wpn/day (FM 101-10-1)

Value of x	x=0.0	x=1.0	x=1.25	x=1.5	x=1.75	x=2	x=3	x=4
No. of Wpns	1	54	67	81	94	108	162	216

Divisional Rate

55	231	55	54	54	54	54	54	54
60	231	60	54	54	54	54	54	54
65	231	65	54	54	54	54	54	54
75	231	75	58	55	54	54	54	54
80	231	80	61	56	55	55	54	54
105	231	105	83	73	67	63	57	56
125	231	125	105	93	85	79	68	63
150	231	150	134	122	114	107	92	84
175	231	175	163	154	147	142	127	118
200	231	200	193	188	184	180	170	163

Table B4.   Ammunition in Rounds per Weapon per Day

Thesis Methodology Results - 155mm Howitzer
Armored or Mechanized Division - Succeeding Days of Defense
Heavy Level of Commitment

Weapons in Division - 54

Theater Rate - 54 rds/wpn/day (SB 38-26)

Single Weapon Rate - 140 rds/wpn/day (FM 101-10-1)

Value of x	x=0.0	x=1.0	x=1.25	x=1.5	x=1.75	x=2	x=3	x=4
No. of Wpns	1	54	67	81	94	108	162	216
Divisional Rate								
55	140	53	54	54	54	54	54	54
60	140	60	54	54	54	54	54	54
65	140	65	56	55	54	54	54	54
70	140	70	60	57	55	55	54	54
80	140	80	70	64	61	59	56	55
90	140	90	80	74	71	68	62	59
100	140	100	92	86	82	79	72	68
110	140	110	104	99	95	93	85	81
120	140	120	116	112	110	107	101	97

Table B5.   Ammunition in Rounds per Weapon per Day

Thesis Methodology Results - 105mm Tank Gun
Armored Division - 1st Day of Attack
Heavy Level of Commitment

Weapons in Division - 324

Theater Rate - 5.6 rds/wpn/day (SB 38-26)

Single Weapon Rate - 52 rds/wpn/day (FM 101-10-1)

Value of x	x=0.0	x=1.0	x=1.25	x=1.5	x=1.75	x=2	x=3	x=4
No. of Wpns	1	324	405	486	567	648	972	1296

Divisional Rate

6	52	6	6	6	6	6	6	6
8	52	8	6	6	6	6	6	6
10	52	10	6	6	6	6	6	6
15	52	15	10	8	7	6	6	6
20	52	20	14	11	10	9	7	6
25	52	25	20	17	15	13	10	8
30	52	30	26	23	20	19	15	13
35	52	35	31	29	27	25	21	19
40	52	40	37	35	34	33	29	27

Table B6. Ammunition in Rounds per Weapon per Day

Thesis Methodology Results - 105mm Tank Gun
Armored Division - Succeeding Days of Attack
Heavy Level of Commitment

Weapons in Division - 324

Theater Rate - 5.6 rds/wpn/day (SB 38-26)

Single Weapon Rate - 28 rds/wpn/day (FM 101-10-1)

Value of x	x=0.0	x=1.0	x=1.25	x=1.5	x=1.75	x=2	x=3	x=4
No. of Wpns	1	324	405	486	567	648	972	1296
Divisional Rate								
6	28	6	6	6	6	6	6	6
8	28	8	6	6	6	6	6	6
10	28	10	7	6	6	6	6	6
12	28	12	9	8	7	7	6	6
15	28	15	13	11	10	9	8	7
20	28	20	18	17	16	15	13	12
25	28	25	24	24	23	23	22	21

Table 87. Ammunition in Rounds per Weapon per Day

Thesis Methodology Results - 105mm Tank Gun
Armored Division - 1st Day of Defense
Very Heavy Level of Commitment

Weapons in Division - 324

Theater Rate - 5.6 rds/wpn/day (SB 38-26)

Single Weapon Rate - 78 rds/wpn/day (FM 101-10-1)

Value of x	x=0.0	x=1.0	x=1.25	x=1.5	x=1.75	x=2	x=3	x=4
No. of Wpns.	1	324	405	486	567	648	972	1296

Divisional Rate

6	78	6	6	6	6	6	6	6
10	78	10	6	6	6	6	6	6
15	78	15	8	6	6	6	6	6
25	78	25	16	12	10	9	7	6
35	78	35	27	22	19	16	12	9
50	78	50	44	40	37	34	28	24
65	78	65	62	60	58	57	52	49

Table B8. Ammunition in Rounds per Weapon per Day

Thesis Methodology Results - 105mm Tank Gun
Armored Division- Succeeding Days of Defense
Very Heavy Level of Commitment

Weapons - Division - 324

Theater Rate - 5.6 rds/wpn/day (SB 38-26)

Single Weapon Rate - 47 rds/wpn/day (FM 101-10-1)

Value of x	x=0.0	x=1.0	x=1.25	x=1.5	x=1.75	x=2	x=3	x=4
No. of Wpns	1	324	405	486	567	648	972	1296

Divisional Rate

	x=0.0	x=1.0	x=1.25	x=1.5	x=1.75	x=2	x=3	x=4
6	47	6	6	6	6	6	6	6
8	47	8	6	6	6	6	6	6
10	47	10	6	6	6	6	6	6
15	47	15	10	8	7	6	6	6
20	47	20	15	12	10	10	7	7
25	47	25	21	18	16	14	11	10
30	47	30	27	24	22	21	17	15
35	47	35	32	31	29	28	24	22
40	47	40	38	37	36	35	33	31

Table B9.   Ammunition in Rounds per Weapon per Day

Thesis Methodology Results - TOW Antitank Missile
Armored Division - 1st Day of Attack
Very Heavy Level of Commitment

Weapons in Division - 90

Theater Rate - 0.24 rds/wpn/day (SB 38-26)

Single Weapon Rate - 14 rds/wpn/day (New FM 101-10-1)

Value of x	x=0.0	x=1.0	x=1.25	x=1.5	x=1.75	x=2	x=3	x=4
No. of Wpns	1	90	112	135	157	180	270	360

Divisional Rate

	x=0.0	x=1.0	x=1.25	x=1.5	x=1.75	x=2	x=3	x=4
0.75	14	0.75	0.24	0.24	0.24	0.24	0.24	0.24
1.5	14	1.5	0.38	0.26	0.24	0.24	0.24	0.24
3.0	14	3.0	1.37	0.79	0.54	0.41	0.27	0.25
5.0	14	5.0	3.36	2.45	1.89	1.52	0.84	0.59
8.0	14	8.0	6.77	5.91	5.27	4.78	3.56	2.90
12.0	14	12.0	11.56	11.22	10.93	10.69	10.00	9.53

Table B10. Ammunition in Rounds per Weapon per Day

Thesis Methodology Results - TOW Antitank Missile
Armored Division - Succeeding Days of Attack
Very Heavy Level of Commitment

Weapons in Division - 90

Theater Rate - 0.24 rds/wpn/day (SB 38-26)

Single Weapon Rate - 7 rds/wpn/day (New FM 101-10-1)

Value of x	x=0.0	x=1.0	x=1.25	x=1.5	x=1.75	x=2	x=3	x=4
No. of Wpns	1	90	112	135	157	180	270	360

Divisional Rate

0.75	7	0.75	0.27	0.24	0.24	0.24	0.24	0.24
1.5	7	1.5	0.72	0.45	0.35	0.30	0.25	0.24
3.0	7	3.0	2.24	1.77	1.47	1.25	0.80	0.61
5.0	7	5.0	4.57	4.25	4.00	3.80	3.24	2.90

Table Bll.   Ammunition in Rounds per Weapon per Day

Thesis Methodology Results - TOW Antitank Missile
Armored Division - 1st Day of Defense
Very Heavy Level of Commitment

Weapons in Division - 90

Theater Rate - 0.24 rds/wpn/day (SB 38-26)

Single Weapon Rate - 16 rds/wpn/day (New FM 101-10-1)

Value of x	x=0.0	x-1.0	x=1.25	x=1.5	x=1.75	x=2	x=3	x=4
No. of Wpns	1	90	112	135	157	180	270	360
Divisional Rate								
0.75	16	0.75	0.24	0.24	0.24	0.24	0.24	0.24
1.5	16	1.5	0.34	0.25	0.24	0.24	0.24	0.24
3.0	16	3.0	1.20	0.65	0.44	0.35	0.26	0.24
5.0	16	5.0	3.08	2.10	1.55	1.20	0.62	0.43
8.0	16	8.0	6.41	5.35	4.60	4.04	2.74	2.10
12.0	16	12.0	11.14	10.49	9.96	9.53	8.33	7.58

Table B15. Ammunition in Rounds per Weapon per Day

Thesis Methodology Results - TOW Antitank Missile
Armored Division - Succeeding Days of Defense
Very Heavy Level of Commitment

Weapons in Division - 90

Theater Rate - 0.24 rds/wpn/day (SB 38-26)

Single Weapon Rate - 16 rds/wpn/day (New FM 101-10-1)

Value of x	x=0.0	x=1.0	x=1.25	x=1.5	x=1.75	x=2	x=3	x=4
No. of Wpns	1	90	112	135	157	180	270	360

Divisional Rate

0.75	16	0.75	0.25	0.24	0.24	0.24	0.24	0.24
1.5	16	1.5	0.52	0.32	0.27	0.25	0.24	0.24
3.0	16	3.0	1.81	1.23	0.91	0.72	0.41	0.32
5.0	16	5.0	4.01	3.35	2.88	2.54	1.74	1.35
6.0	16	6.0	5.17	4.59	4.15	3.80	2.93	2.44
7.0	16	7.0	6.36	5.89	5.51	5.21	4.39	3.89
8.0	16	8.0	7.57	7.23	6.96	6.73	6.09	5.67

Table B13.   Ammunition in Rounds per Weapon per Day

Thesis Methodology Results - Dragon Antitank Missile
Mechanized Division - 1st Day of Attack
Very Heavy Level of Commitment

Weapons in Division - 260

Theater Rate - 0.3 rds/wpn/day (SB 38-26)

Single Weapon Rate - 5 rds/wpn/day (New FM 101-10-1)

Value of x	x=0.0	x=1.0	x=1.25	x=1.5	x=1.75	x=2	x=3	x=4
No. of Wpns	1	260	325	390	455	520	780	1040
Divisional Rate								
0.5	5	0.5	0.30	0.30	0.30	0.30	0.36	0.30
1.0	5	1.0	0.5	0.37	0.33	0.31	0.30	0.30
1.5	5	1.5	0.93	0.67	0.53	0.46	0.35	0.32
2.0	5	2.0	1.45	1.13	0.93	0.80	0.54	0.45
2.5	5	2.5	2.01	1.69	1.46	1.30	0.93	0.76
3.0	5	3.0	2.59	2.30	2.08	1.92	1.50	1.27
3.5	5	3.5	3.18	2.95	2.76	2.61	2.21	1.97
4.0	5	4.0	3.78	3.62	3.48	3.37	3.05	2.84

Table B14. Ammunition in Rounds per Weapon per Day

Thesis Methodology Results - Dragon Antitank Missile
Mechanized Division - Succeeding Days of Attack
Very Heavy Level of Commitment

Weapons in Division - 260

Theater Rate - 0.3 rds/wpn/day (SB 38-26)

Single Weapon Rate - 3 rds/wpn/day (New FM 101-10-1)

Value of x	x=0.0	x=1.0	x=1.25	x=1.5	x=1.75	x=2	x=3	x=4
No. of Wpns	1	260	325	390	455	520	780	1040
Divisional Rate								
0.5	3	0.5	0.31	0.30	0.30	0.30	0.30	0.30
1.0	3	1.0	0.67	0.52	0.44	0.40	0.33	0.31
1.5	3	1.5	1.21	1.02	0.90	0.80	0.60	0.51
1.75	3	1.75	1.50	1.32	1.20	1.10	0.86	0.74
2.0	3	2.0	1.79	1.64	1.52	1.43	1.96	1.05

Table B15. Ammunition in Rounds per Weapon per Day

Thesis Methodology Results - Dragon Antitank Missile
Mechanized Division - Succeeding Days of Defense
Very Heavy Lefel of Commitment

Weapons in Division - 260

Theater Rate - 0.3 rds/wpn/day (SB 38-26)

Single Weapon Rate - 5 rds/wpn/day (New FM 101-10-1)

Value of x	x=0.0	x=1.0	x=1.25	x=1.5	x=1.75	x=2	x=3	x=4
No. of Wpns	1	260	325	390	455	520	780	1040
Divisional Rate								
0.5	5	0.50	0.30	0.30	0.30	0.30	0.30	0.30
0.75	5	0.75	0.35	0.31	0.30	0.30	0.30	0.30
1.0	5	1.00	0.50	0.37	0.33	0.31	0.30	0.30
1.5	5	1.50	0.93	0.67	0.53	0.46	0.35	0.32
2.0	5	2.00	1.45	1.13	0.93	0.80	0.54	0.45
2.5	5	2.50	2.01	1.69	1.46	1.30	0.93	0.76
3.5	5	3.50	3.18	2.95	2.76	2.61	2.21	1.97
4.0	5	4.00	3.78	3.62	3.48	3.37	3.05	2.84

Table B16. Ammunition in Rounds per Weapon per Day
Attack of Position, Data from Historical Examples and
Combat Simulations as Noted Under Source and Situation
155mm Howitzer

Source	Situation	First Day	Succeed-Days	Protracted
FM 101-10-1	Divisional	192	105	58
FM 101-10-1	Non-Div	207	113	63
N-18104-A 334 Cmbt Days Range 24-53 rds	Invasion Attk South 1st Army 25 Jul 44	41	53	20
N-18104-A 334 Cmbt Days Range 24-53 rds	Attack AAchen 1st Army 1 Oct 44	18	23	20
N-18104-A 192 Cmbt Days Range 17-52 rds	Invasion of Salermo 5th Army 9 Sep 43	36	36	28
N-18104-A 192 Cmbt Days Range 17-52 rds	5th Army Attk German Winter Position 5 Nov 43	20	25	28
N-18104-A 192 Cmbt Days Range 17-52 rds	Battle of Cassino 5th Army 1 May 44	19	53	28
N-18104-A 67 Combat Days Range 3-22 rds	Invasion of Leyte 6th Army 20 Oct 44	22	22	10
N-18104-A 83 Combat Days Range 21-59 rds	Invasion of Okinawa 10th Army 2 Apr 45	23	23	39
N-18104-A 83 Combat Days Range 21-59	Attack of Shuri Line 10th Army 1 Apr 45	26	50	39

Table B16. Ammunition in Rounds per Weapon per Day (Continued)
155mm Howitzer

Source	Situation	First Day	Succeed-ing Days	Protracted
N-18104-A 266 Cmbt Days Range 1-27 rds	Offensive France 6th Army Group 10 Nov 44	16	27	21
R-12885-58-2 (No differentia-tion of days)	Seize of Brest VIII Corps 10 Days	43	43	43
R-12885-58-2	Utah Beach 1 Day	78	--	--
R-12885-58-2 (No differentia-tion of Days)	12th Army Gp 90 Days	20	20	20
N-18104-A 789 Cmbt Days Range 4-37 rds	1st UN Offense 25 Jan 51	24	37	17
N-18104-A 789 Cmbt Days Range 4-37 rds	UN Summer/Fall Offensive Aug 51	27	27	17
N-17439.21 (No differentia-tion of days)	1st Inf. Div. Opn Junction City	25	25	25
(No differentia-tion of Days)	Mideast 6-23 Oct 73	48	48	48
DIVWAG	Final Defense, 4 Hrs. night phase Ratio 8:5-9:3	30 (4 hrs) --		--
U.S. Army Concepts Analysis Agency Nov 75 A76-88 L76-19	Combat Rates FY 78-82 90 Days	W/O CLGP 89 W/CLGP 57 (Avg.)	--	--
Ft. Sill Study	FA Cmbt Study 75 Projecting 1982 Time Frame	444	--	--

(No # days specified)

Table B16.   Ammunition in Rounds per Weapon per Day (Continued)
155mm Howitzer

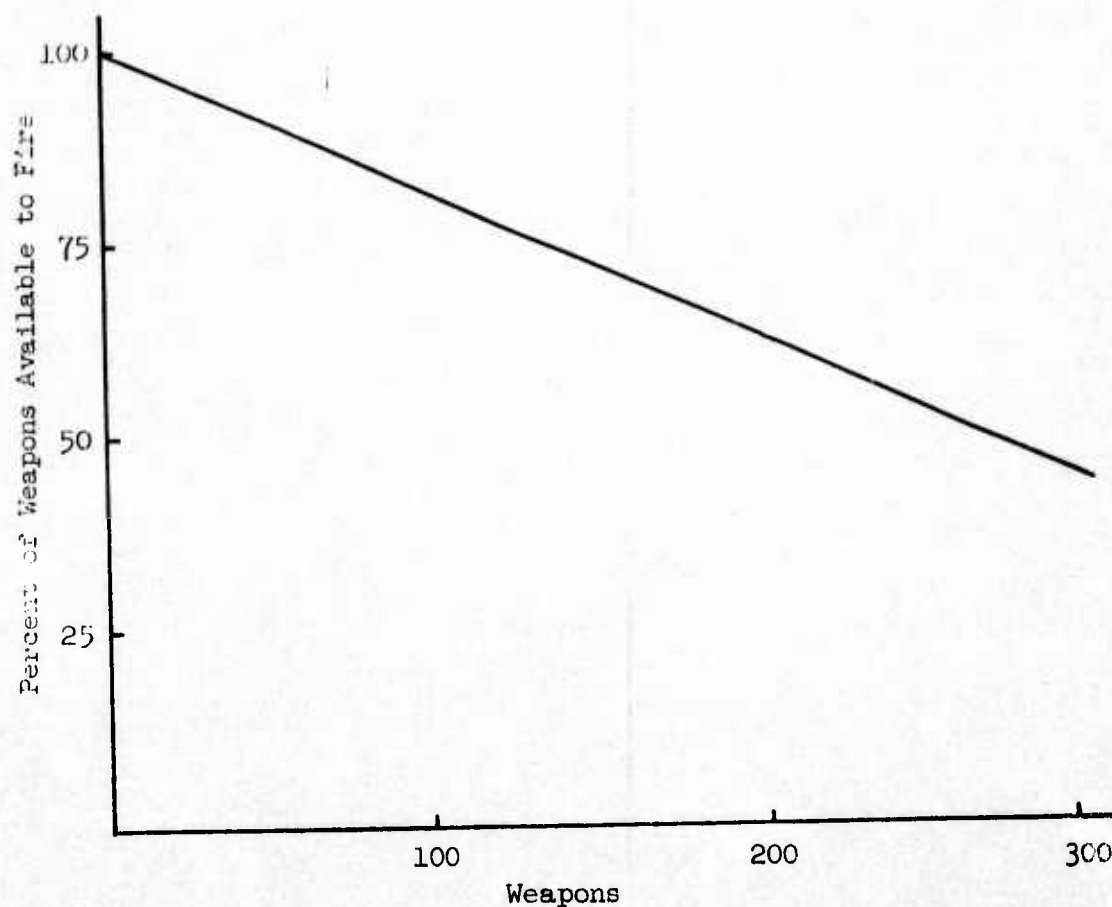| Source	Situation	First Day	Succeed- ing Days	Protracted
CGSC Staff Study 1954 N-18104-A		40	37	
SB 38-26	USAREUR Recommended Stockage	54	47	46
Operations Research Office Study ORO-T-375	Fifth Army Italian Campaign	26	26	26

APPENDIX C

Four-Ninths Rule

and

Modified Four-Ninths Rule

Four-Ninths Rule

As was discussed in Chapter 3, the validity tests are drawn from a modification of the Delphi process. One test which has been provided by an ammunition planner recently returned from an assignment in Europe, is a rule of thumb used to estimate the ammunition requirements for a division. The author has chosen to term this the "four-ninths" rule for estimating divisional ammunition requirements. Although the "four-ninths" rule can be applied to any ammunition consuming weapon in the division, its primary application is intended for artillery. The "four-ninths" rule simply states that at no time will the average rounds per weapon fired exceed the maximum sustained rate of fire for four-ninths of the weapons in the force. This rule is drawn from the following considerations. It is assumed that no more than two-thirds of the weapons of the force will be available to fire. The reason for the nonavailability of the remaining third is not considered by the rule, but only that one-third of the weapons are not available. It is further assumed that for whatever reason one-third of the two-thirds of the weapons available to fire will not fire. This This constitutes two-ninths of the total weapons in the division. Then the sum of the weapons not firing is two-ninths plus one-third or five-ninths. Thus those firing constitute "four-ninths" of the weapons of the force.

Modified Four-Ninths Rule

The modified four-ninths rule assumes that although no more than four-ninths of the weapons can be brought into action at one time, the forty-four percent (four-ninths) applies only to the total force and the availability of weapons to fire increases as the number of weapons decreases. The increase is assumed to be 100% when considering only one weapon. For a force having 300 weapons of a particular type, the modified four-ninths rule is as shown in the graph below.

Modified Four-Ninths Rule